

# Identifying Issues and Anomalies by Combining ML predictions with Measurements

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TSD Topical Meeting

# Study Goal

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**Monitoring issues and anomalies in the system including the target, and the horn system in the beamline is important for experiments to understand the neutrino beam quality.**

**We are planing to monitor the status spill-by-spill.**

**How to observe any issues?**

- ✖ **Near detector data**
- ✖ **Muon Monitor signal**

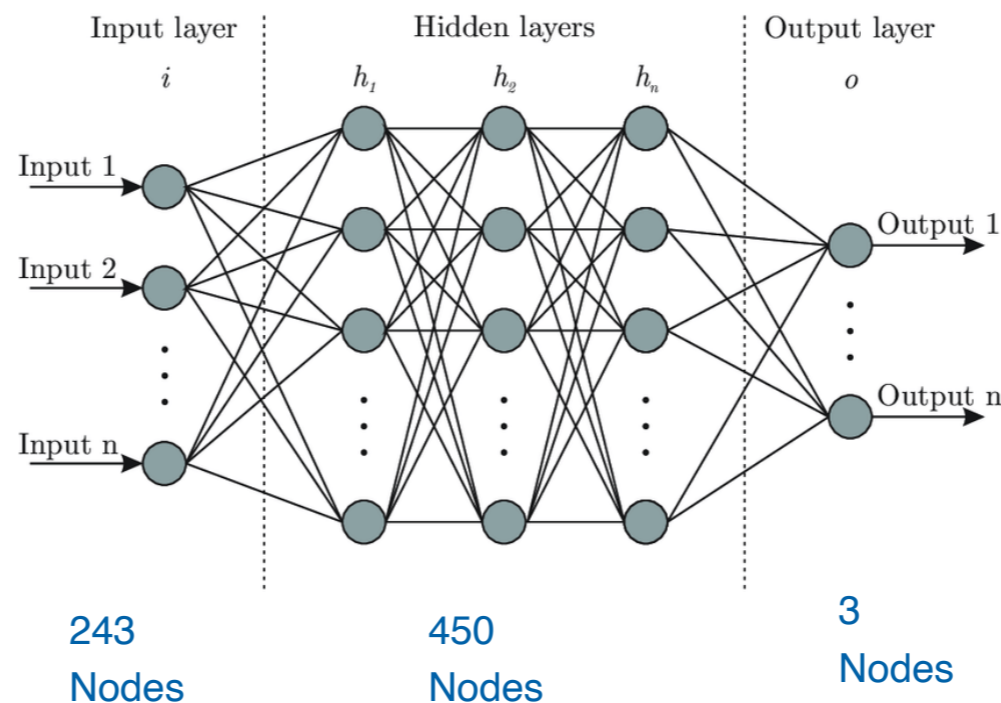
**Therefore, we would like to introduce a method to understand following issues:**

- Long term trends and developing issues**
- Incidents independent from the beam parameters**
- Target related issues , system failure issues, etc**

# Identifying/predicting known incidents from the muon monitor observations

MOTIVATION: A tool to predict and categorize the incidents by taking account muon monitor signals

Muon Monitor Signals  
81x3 pixels



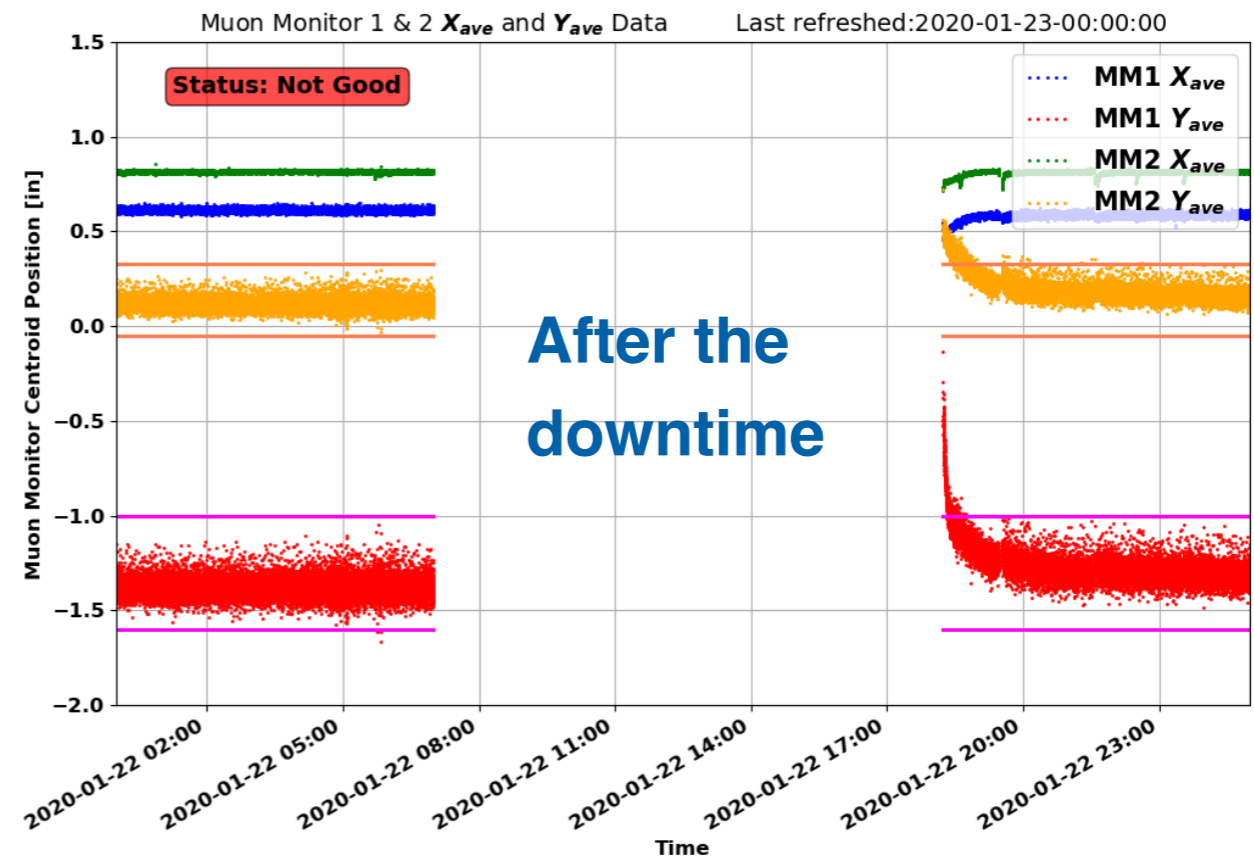
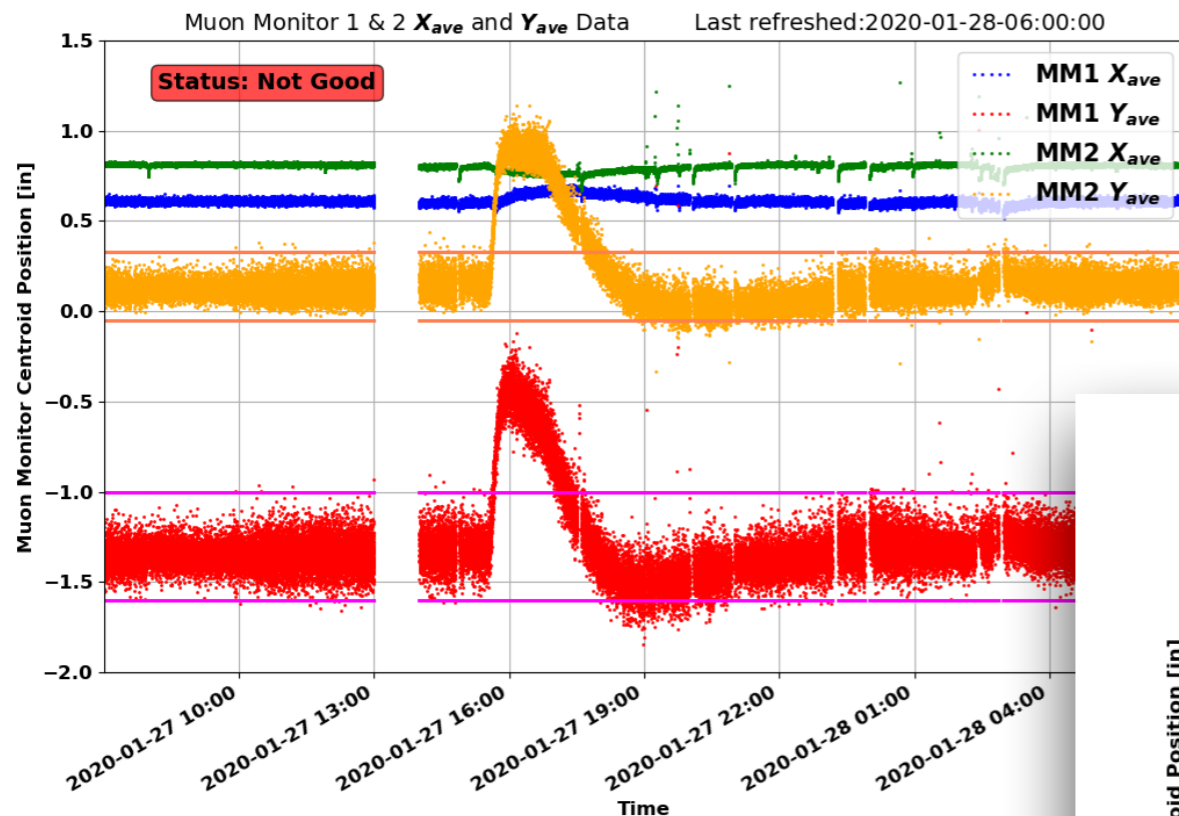
Status

Supervised learning

# Identifying/predicting Incidents

Identifying/predicting Gas Bottle Change or After Down Time Status

*Muon Monitor Response After the Gas Bottle Changes*



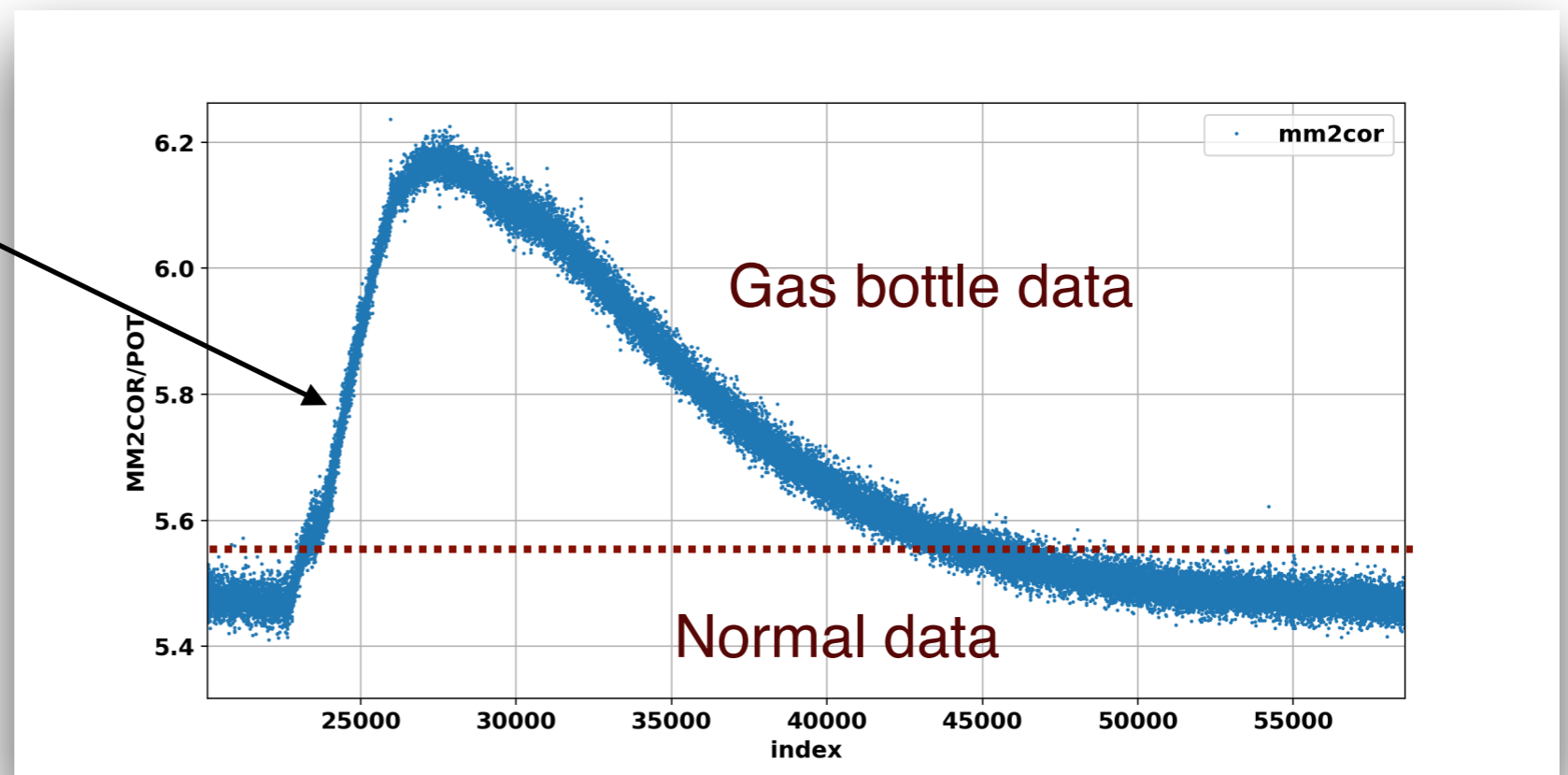
# Training Data Samples

Data samples are prepared according to the following procedure:

- Select few samples from the past incidents by checking the gas pressures, beam intensities, horn current and muon monitor responses
- Setup data selection rules based on integrated signal responses
- Label each data point according to the identified categories
- Shuffle them and randomly select the training and validation samples

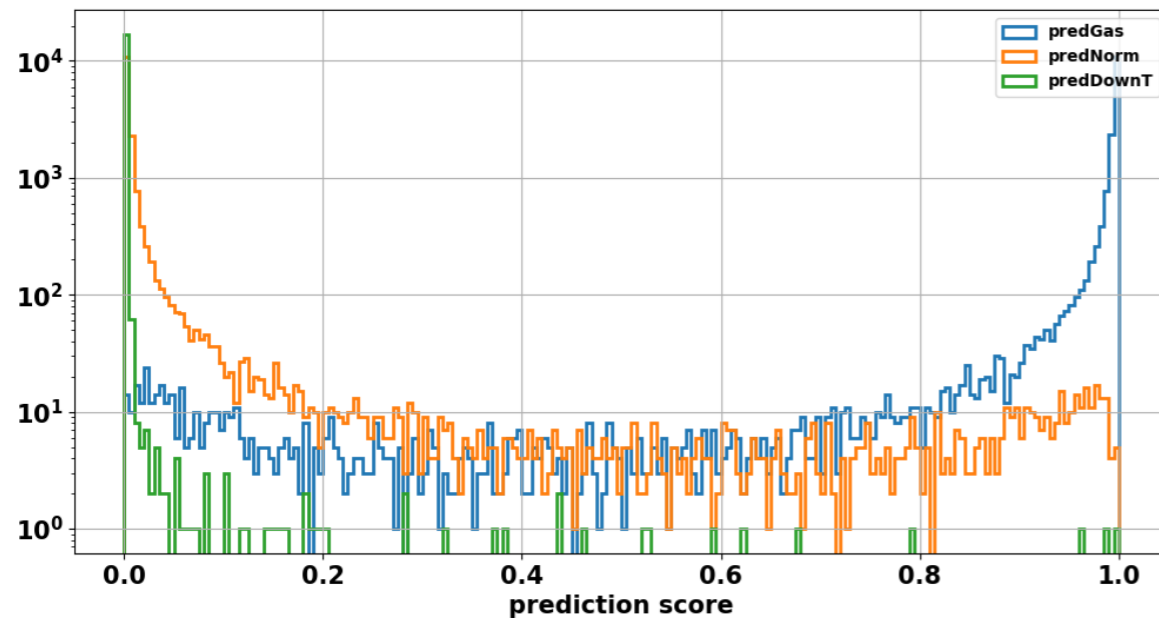
## Example:

Each data point has been labelled as “GasB” data

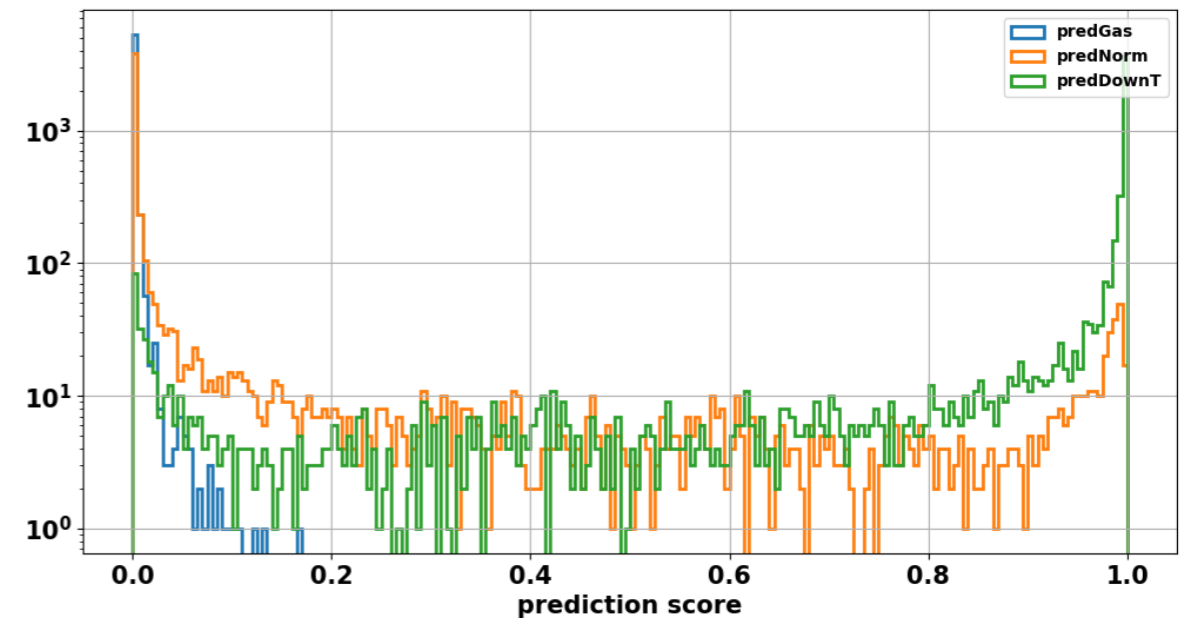


# Model Validation: Status Prediction Score

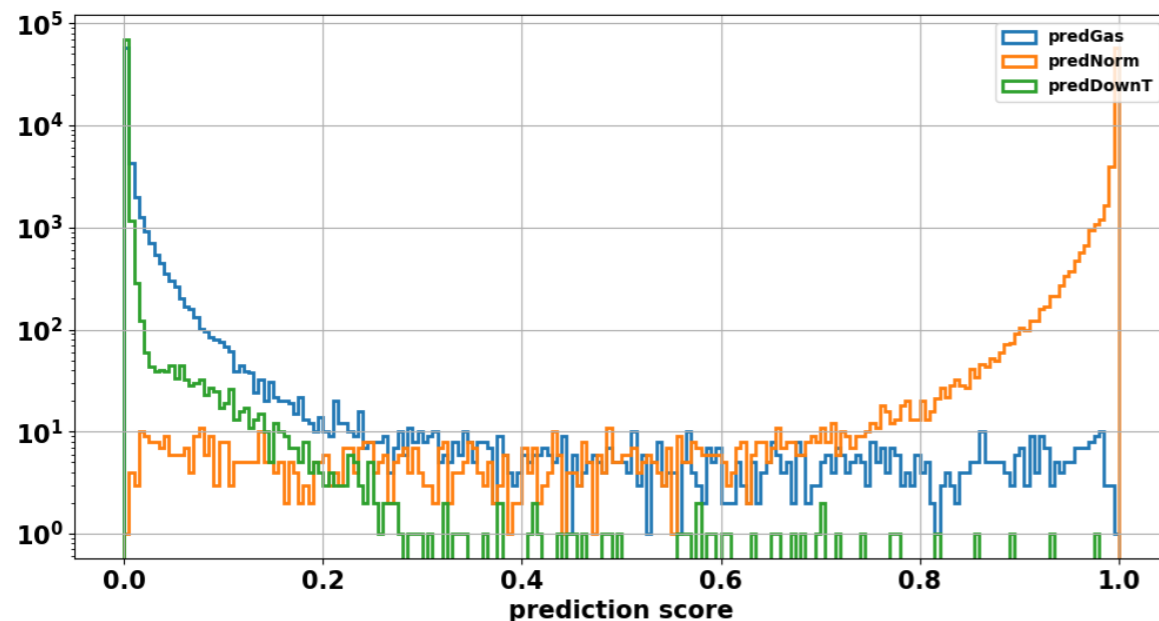
## True Gas Bottle Events



## True After Downtime Events



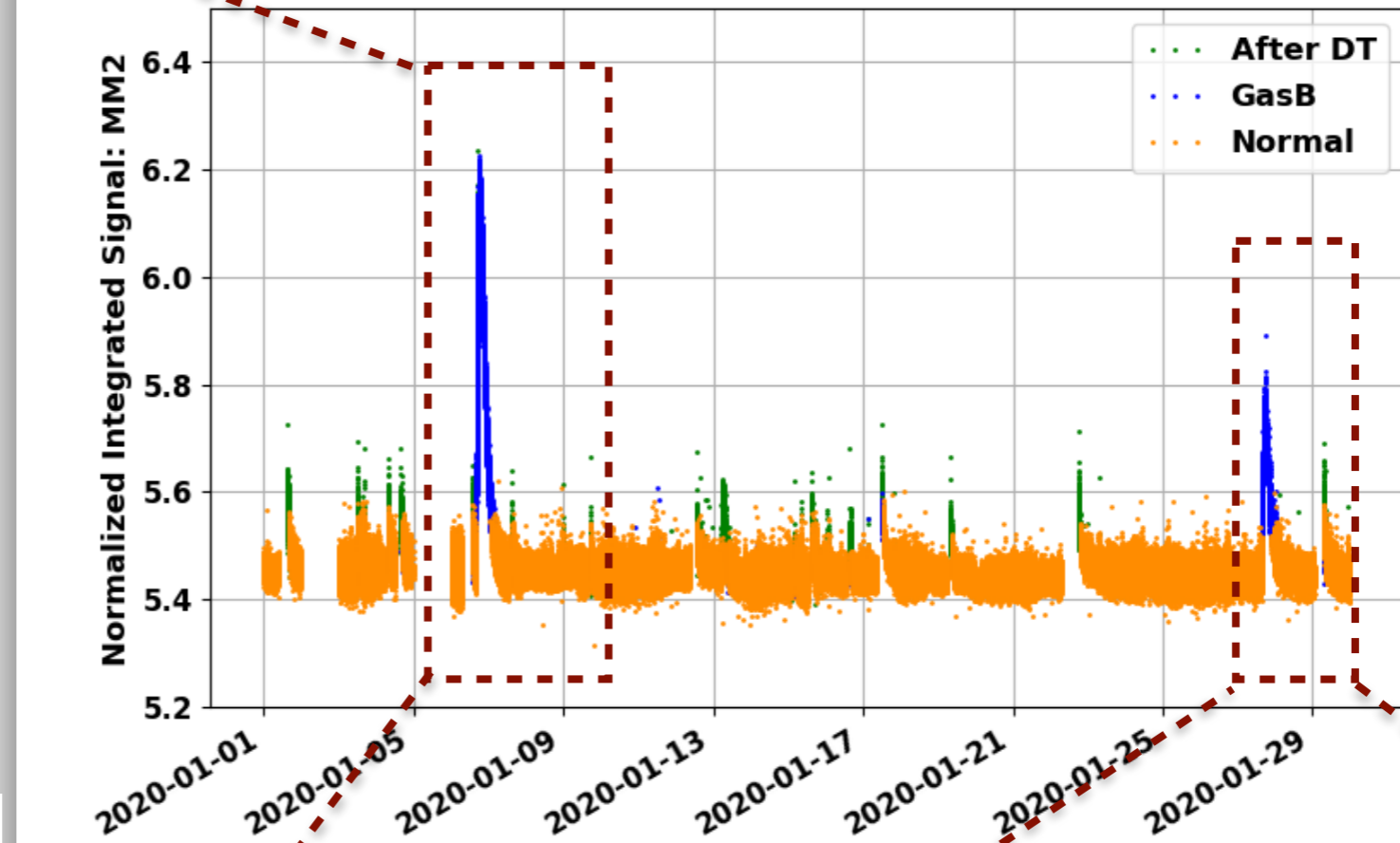
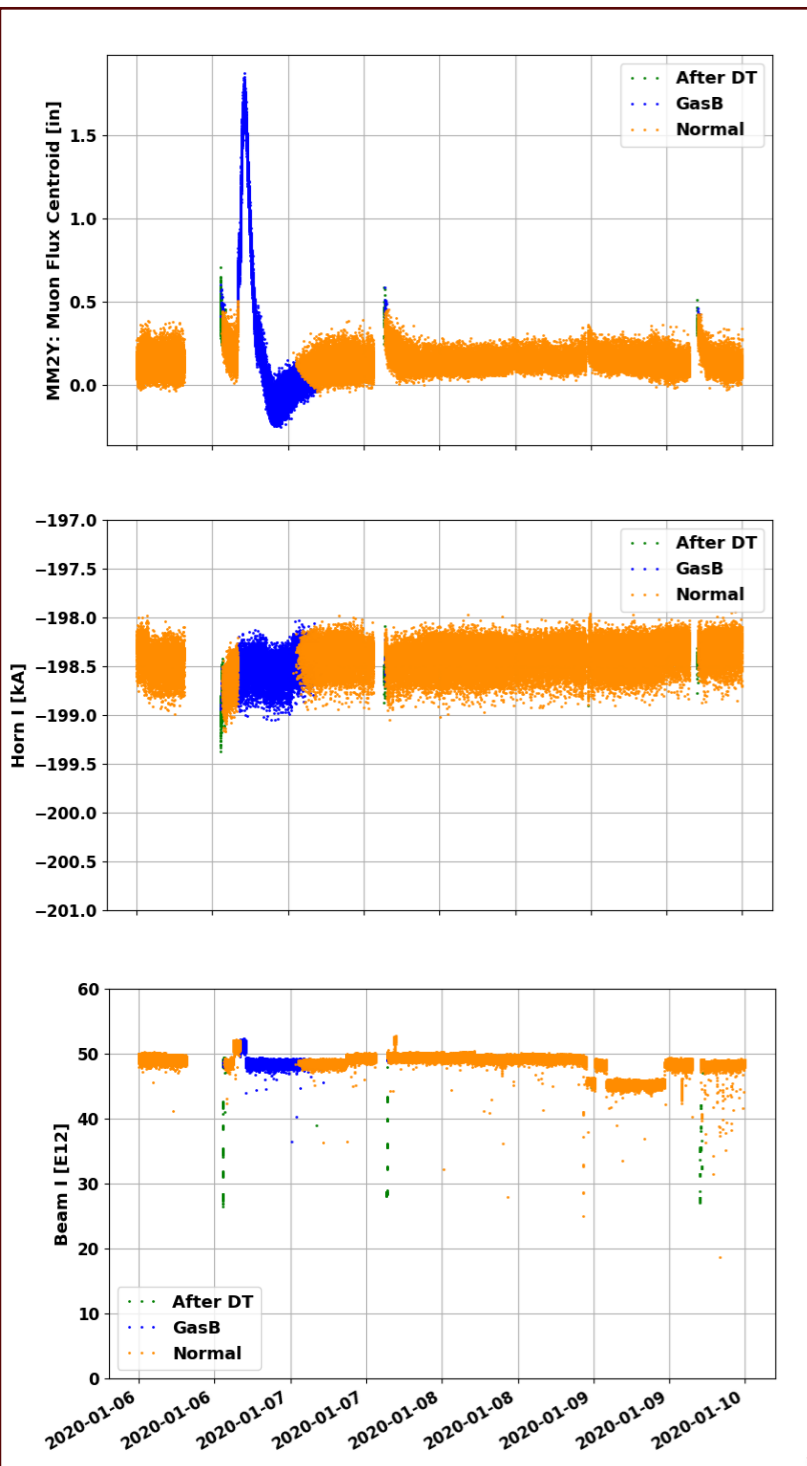
## True Normal Events



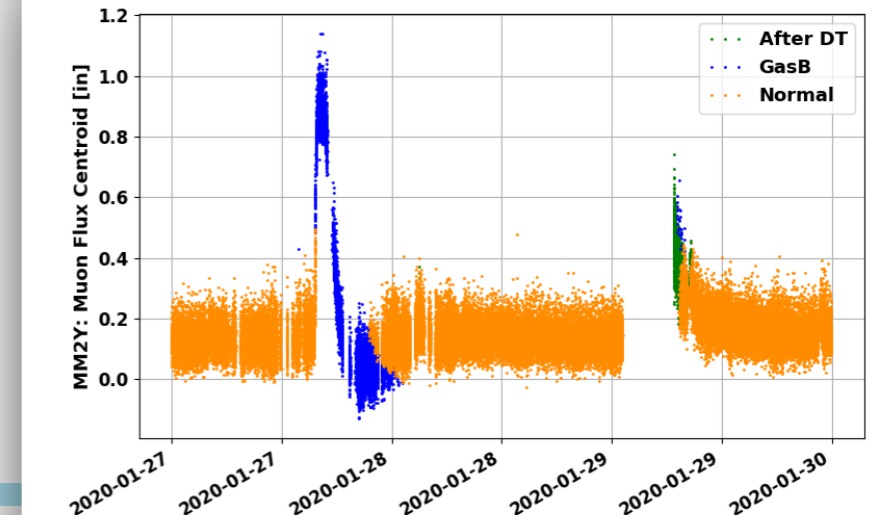
	<i>Pred Gas (%)</i>	<i>Pred DownT (%)</i>	<i>Pred Normal (%)</i>
<i>Gas TRUE (%)</i>	96.68	3.26	0.06
<i>True DownT (%)</i>	0.00	91.76	8.24
<i>True Normal (%)</i>	0.67	0.04	99.29

- Status of the MM observations can be predicted spill to spill
- Labeling the status based on the highest score
- The algorithm will be updated with new categories in the future

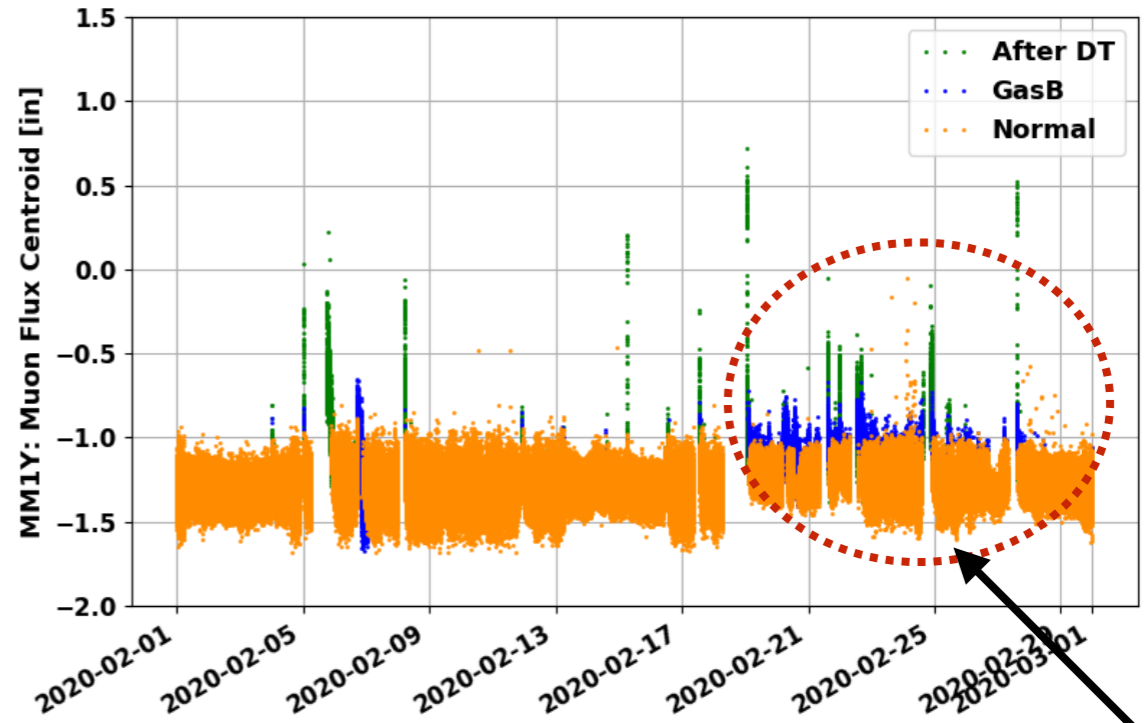
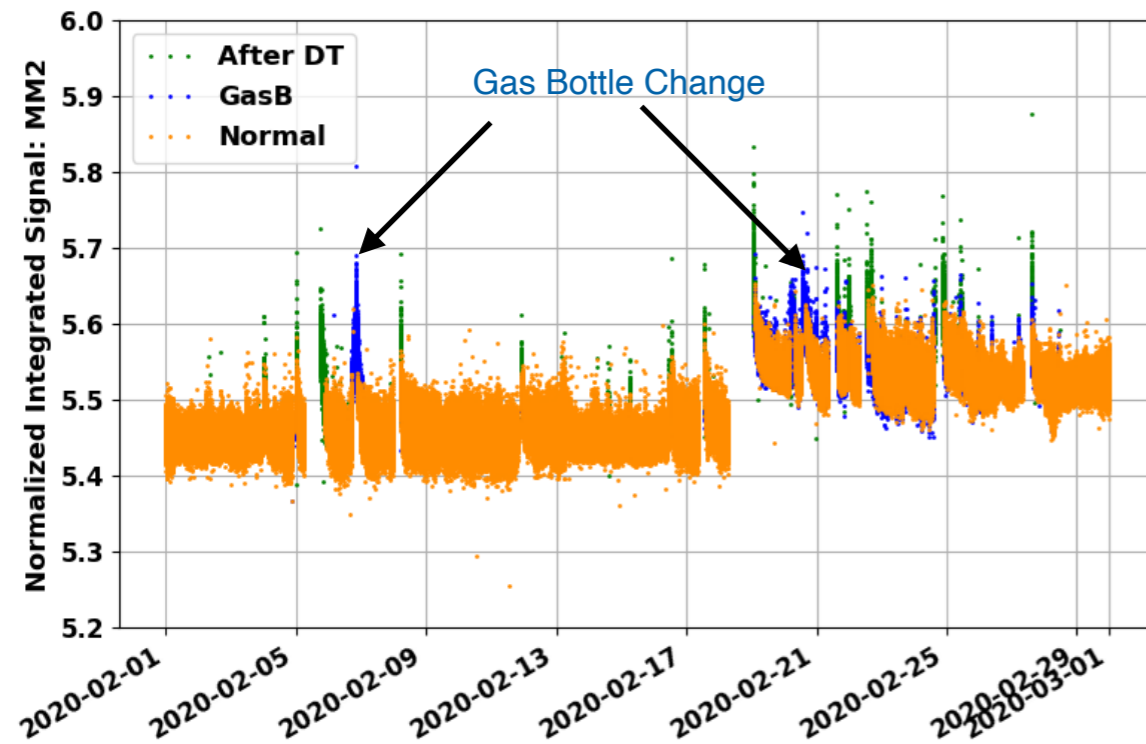
# Testing January 2020



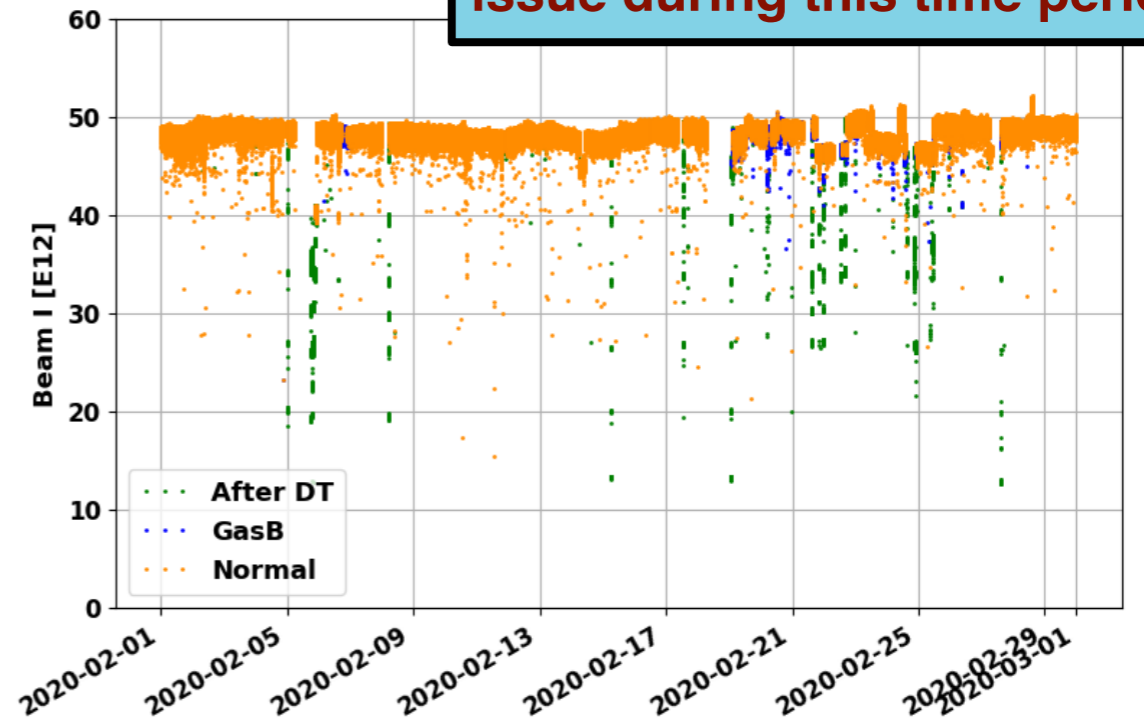
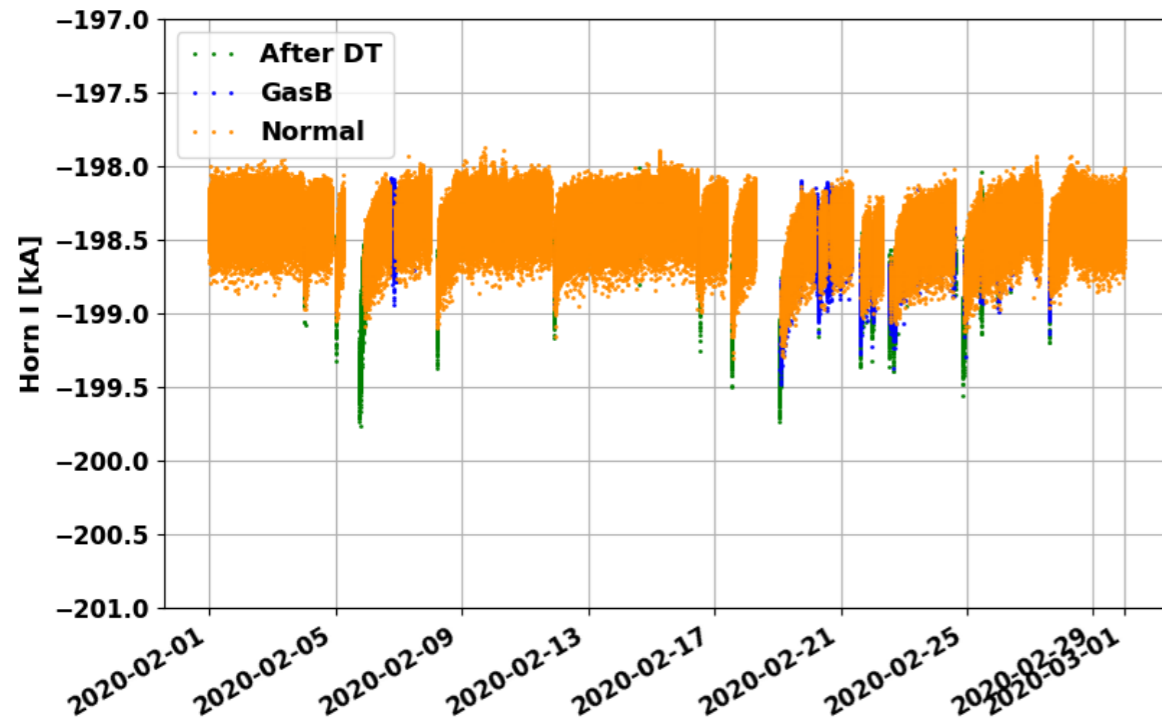
Algorithm is identifying and labeling incidents spill-to-spill with a significant accuracy



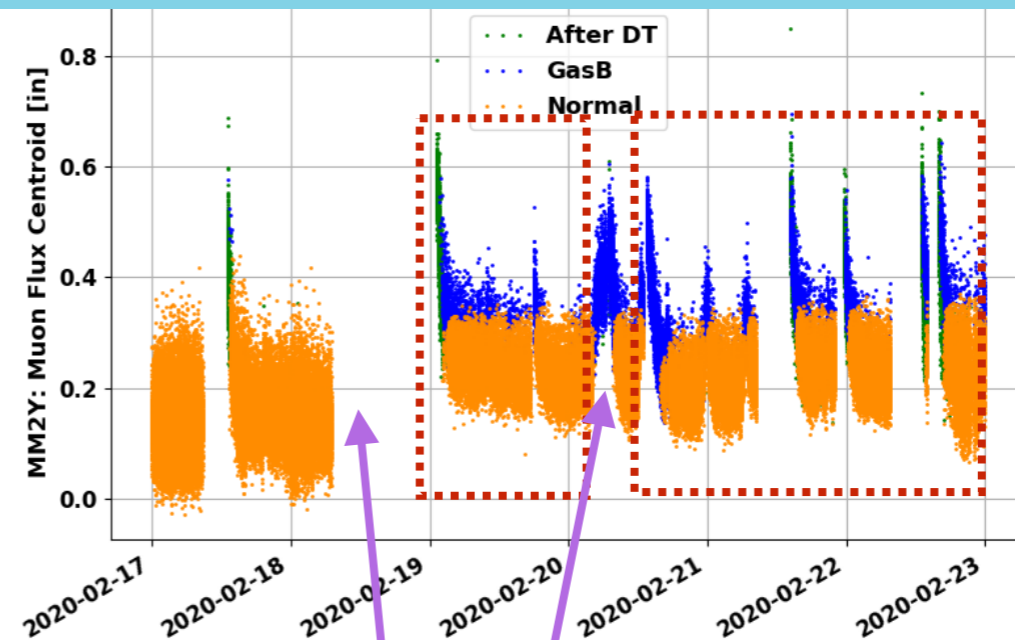
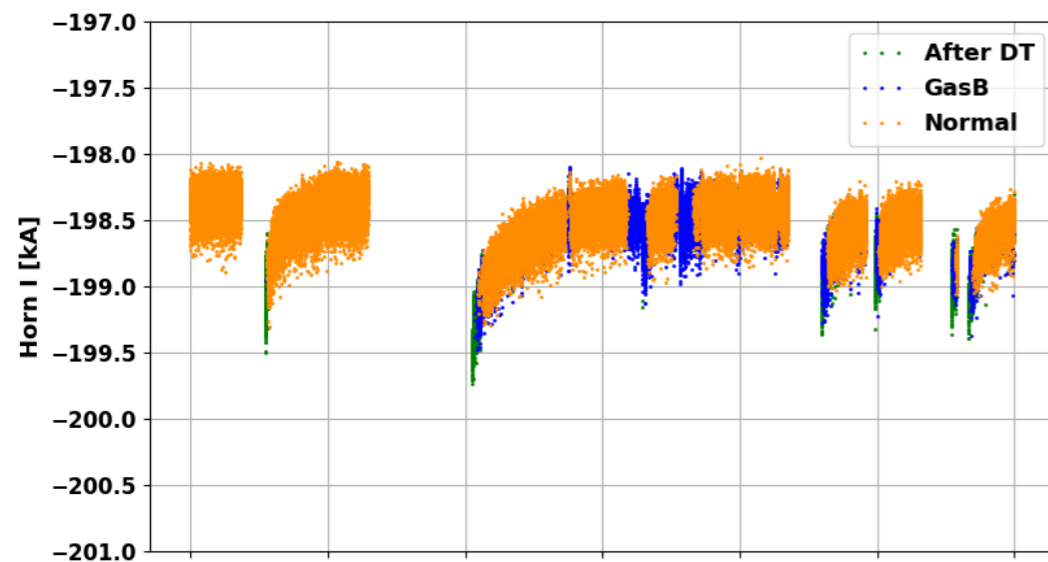
# Testing February 2020



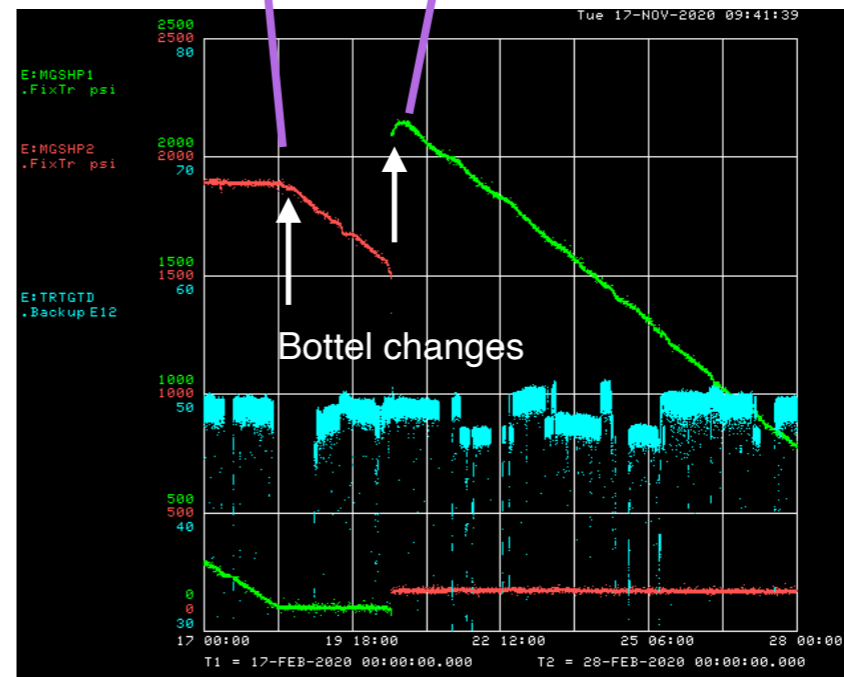
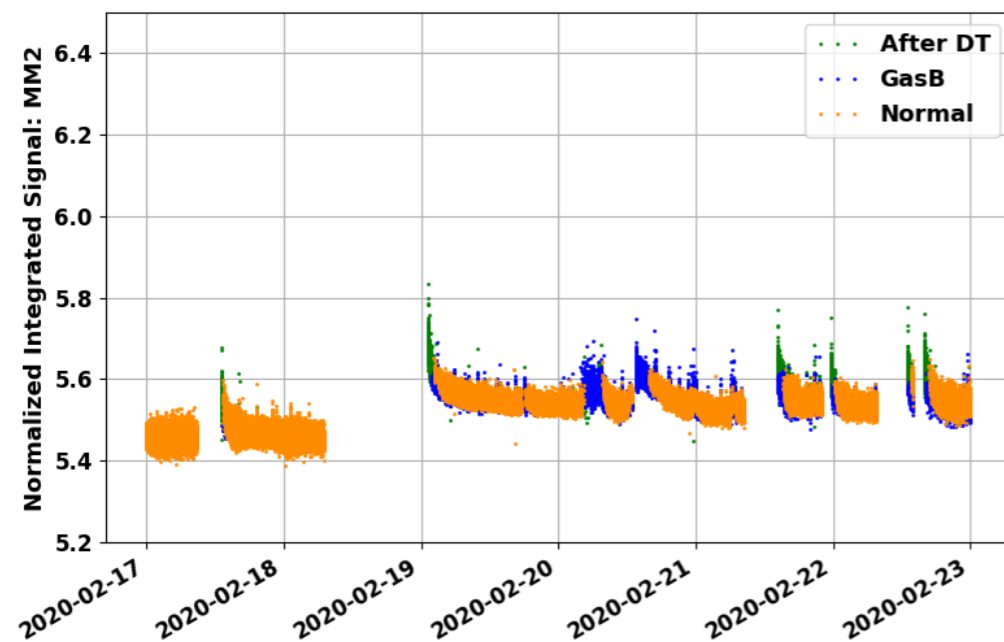
Katsuya found a bad gas quality issue during this time period



# Testing February 2020

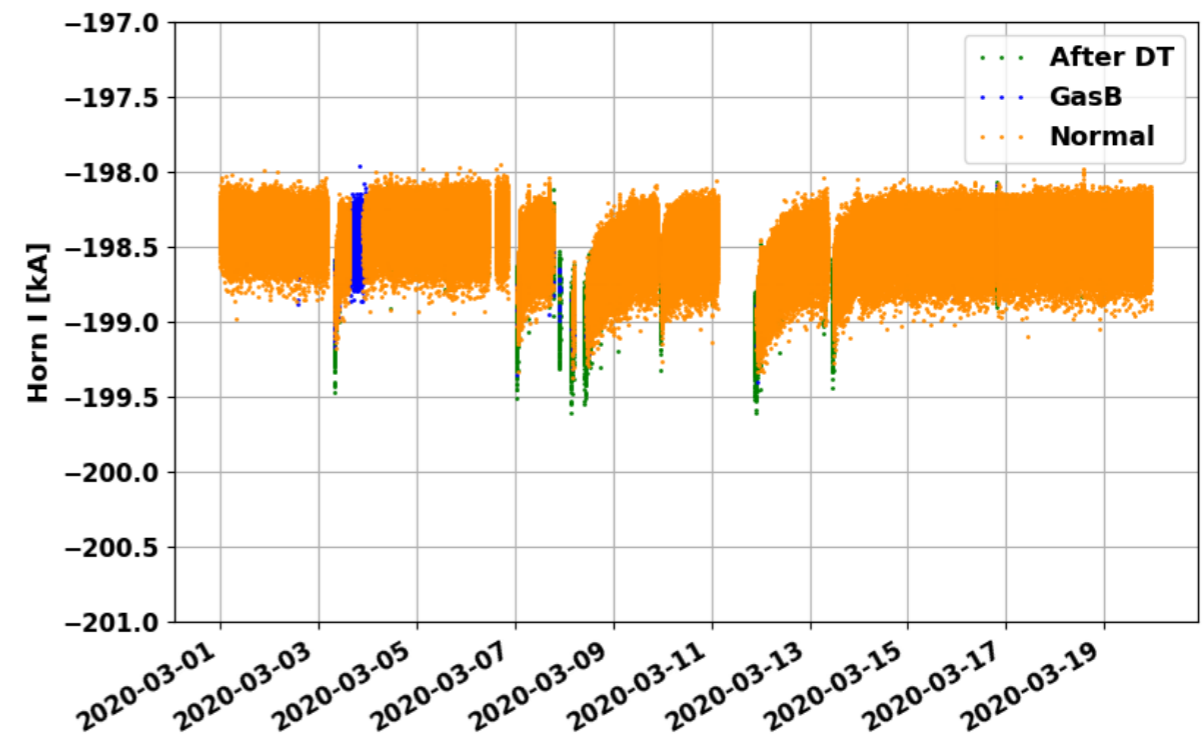
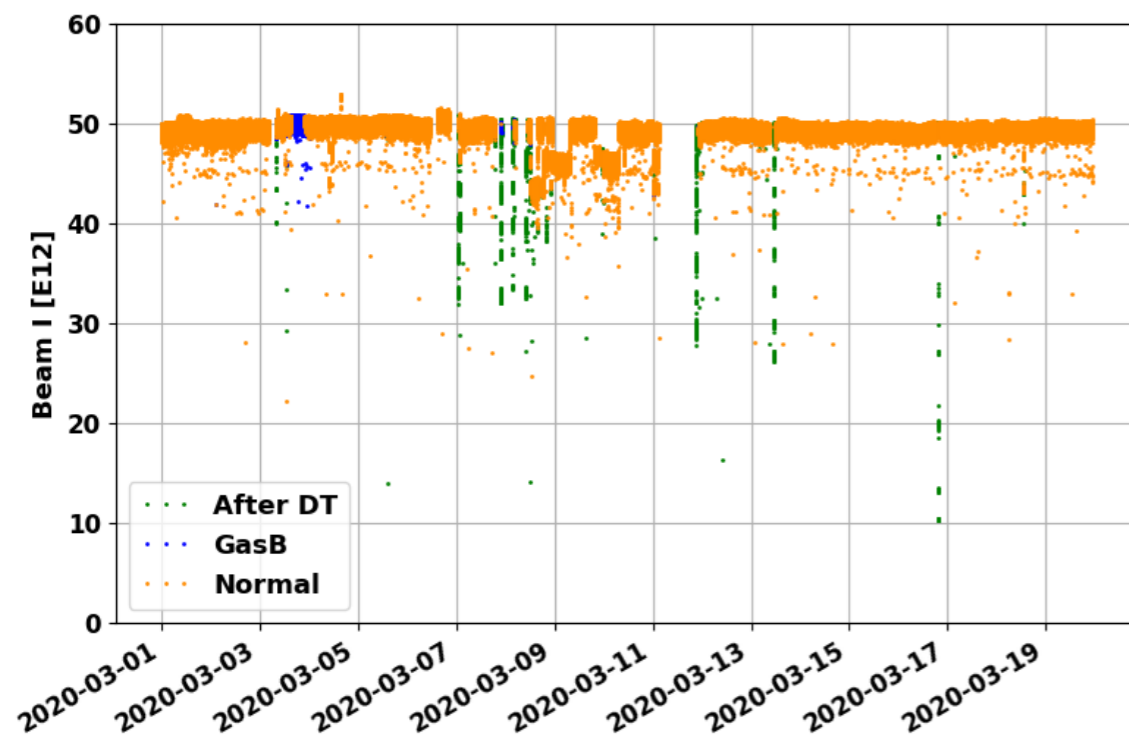
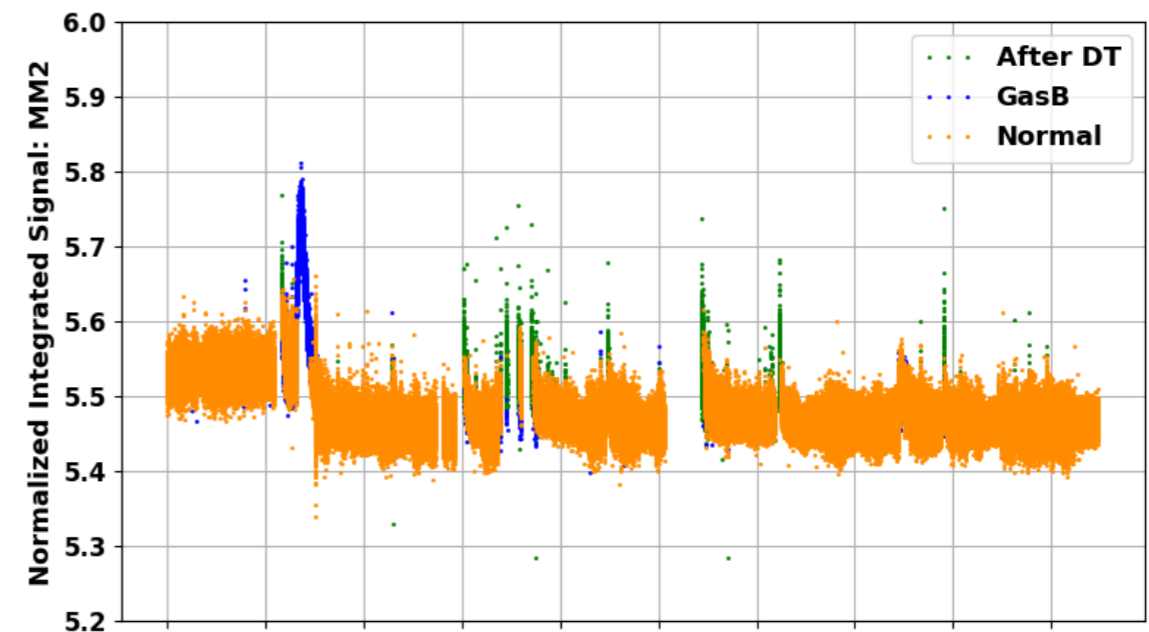
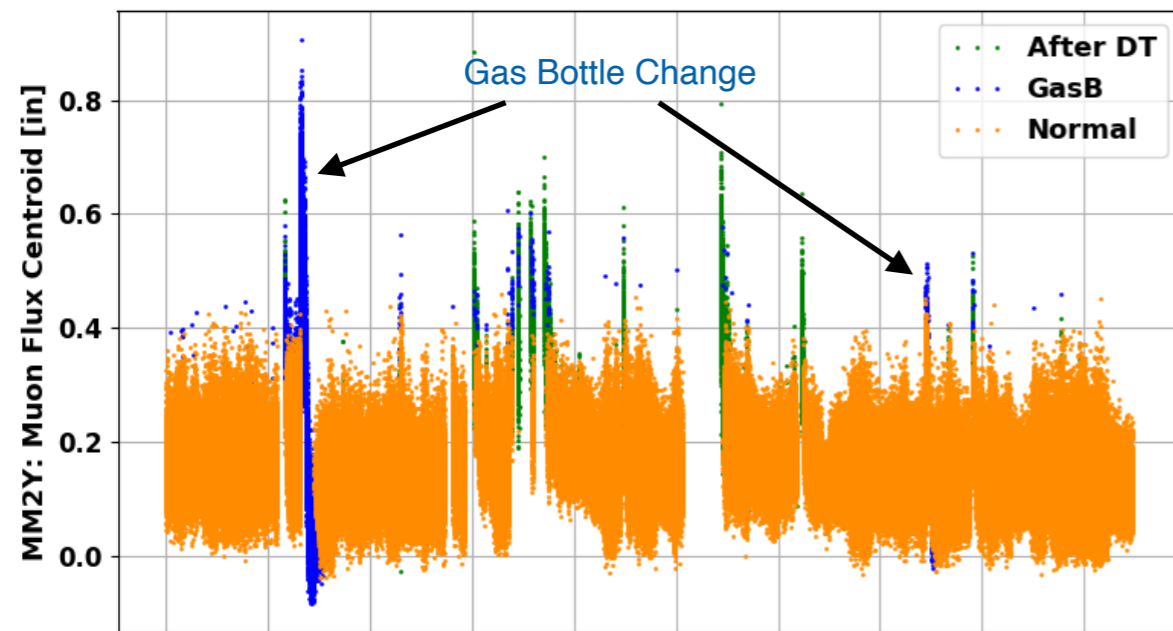


That blue dots  
are false  
Identifications?



**Katsuya requested to change the gas bottles due to the bad gas quality. Does the algorithm predicts false identifications? or that predictions has truly made due the the bad gas quality effects on MM signals?**

# Testing March 2020



## **Next: Defining an Incident Identification Variable**

MOTIVATION: Defining a variable to identify the incidents and anomalies independent from the beam parameters

# Recall: Integrated Signal Definition

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$$\text{Normalized Integrated Signal} = \frac{MM\#COR}{POT}$$

$MM\#COR$  = Muon Monitor integrated signal with pedestal subtractions and calibrations

$MM\#$  = Muon Monitor (1,2 or 3)

$POT$  = Beam Intensity

## Measurement indicates:

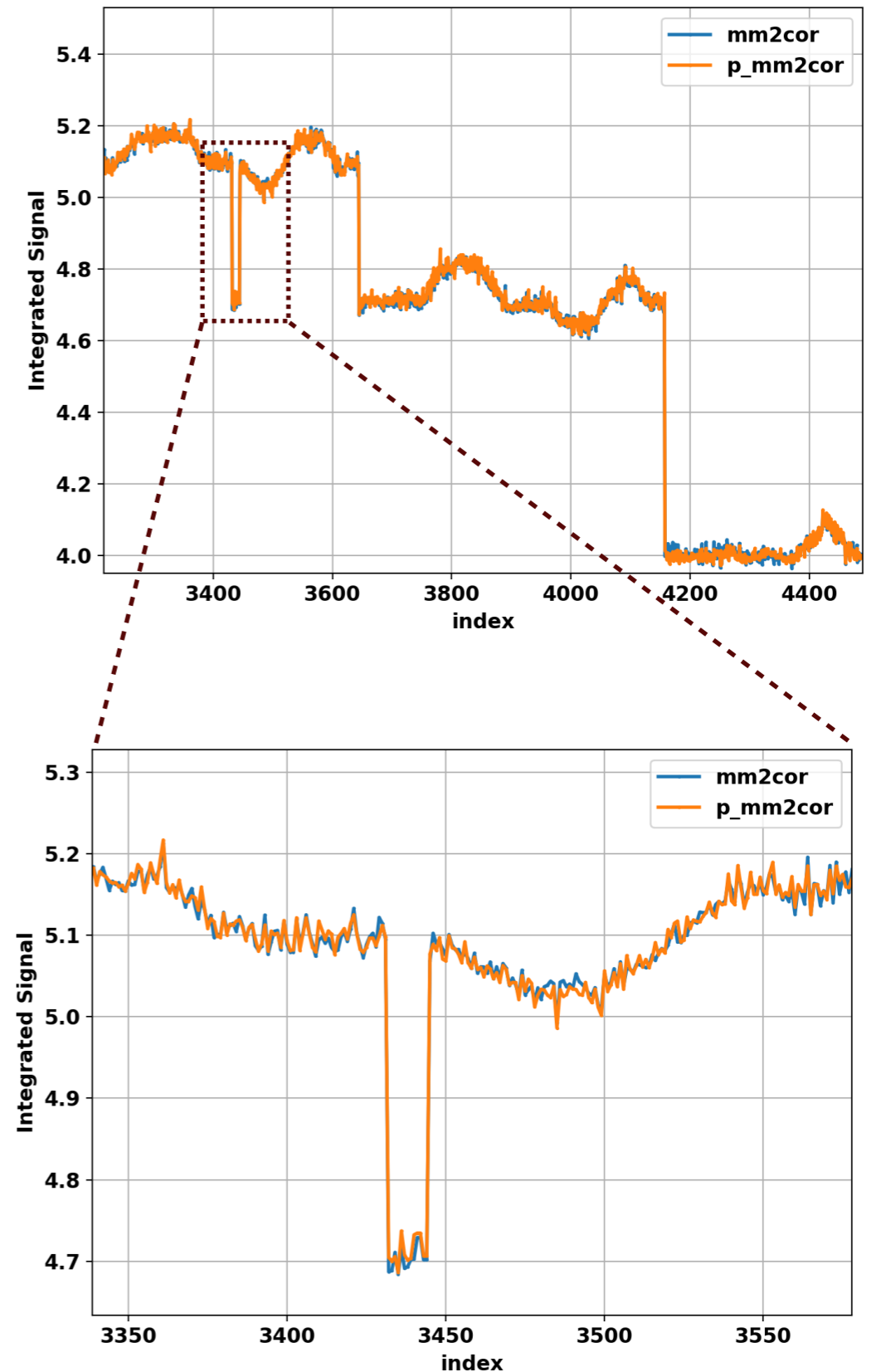
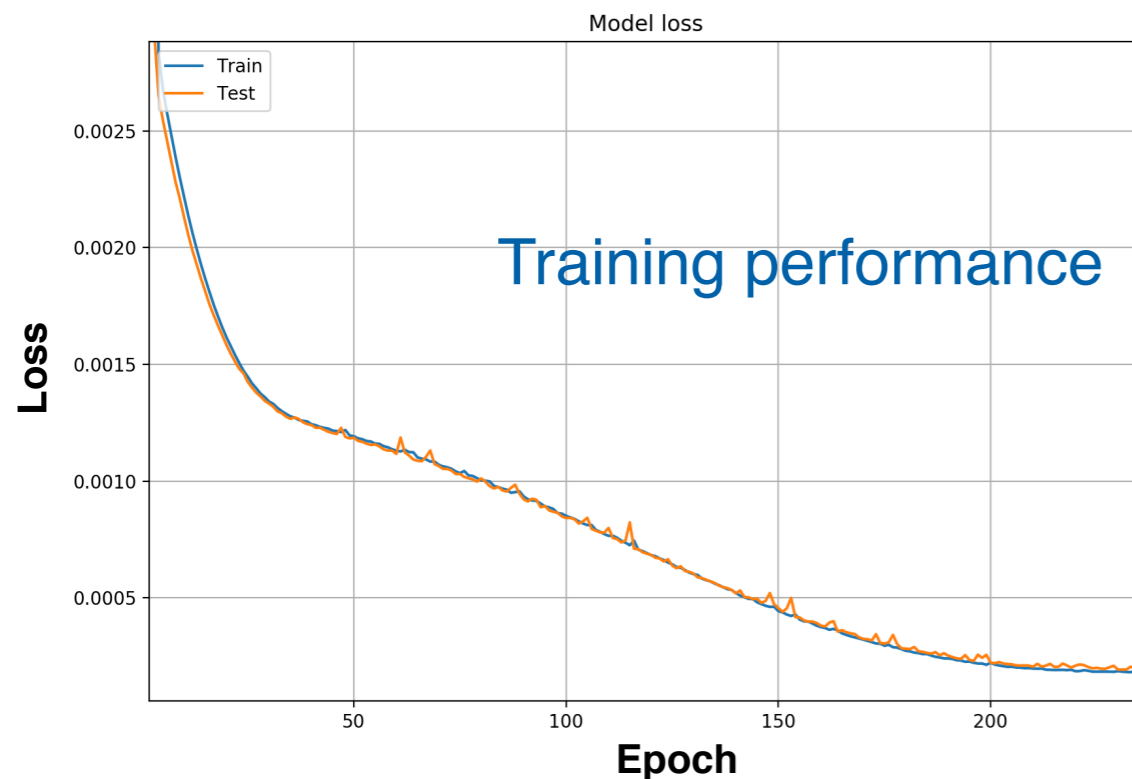
- Proportional to the total muon flux passing through the detector per proton
- Proportional to the total muon energy lost in the detector

## Importance of the measurement:

- Indicates the hadron production related to the target profile
- Sensitive to the horn current variations

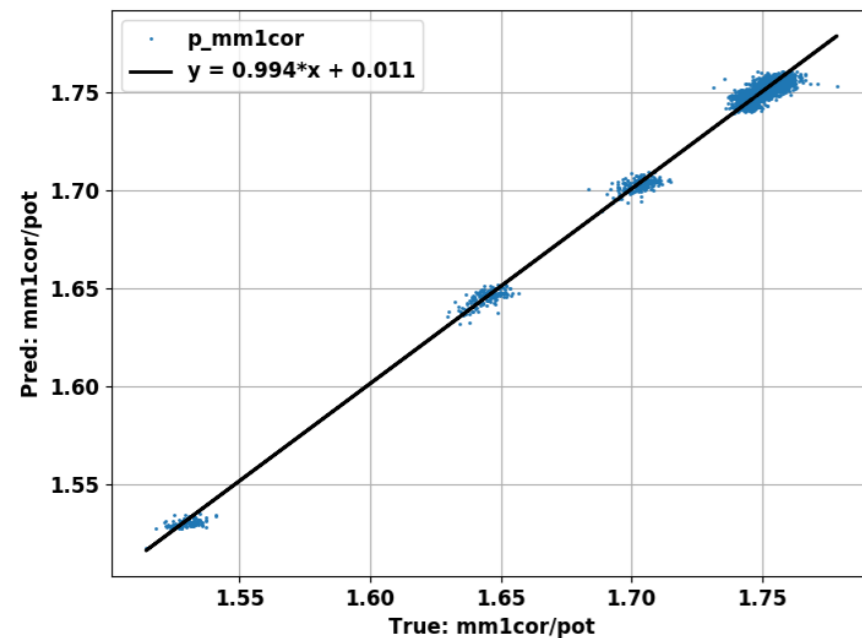
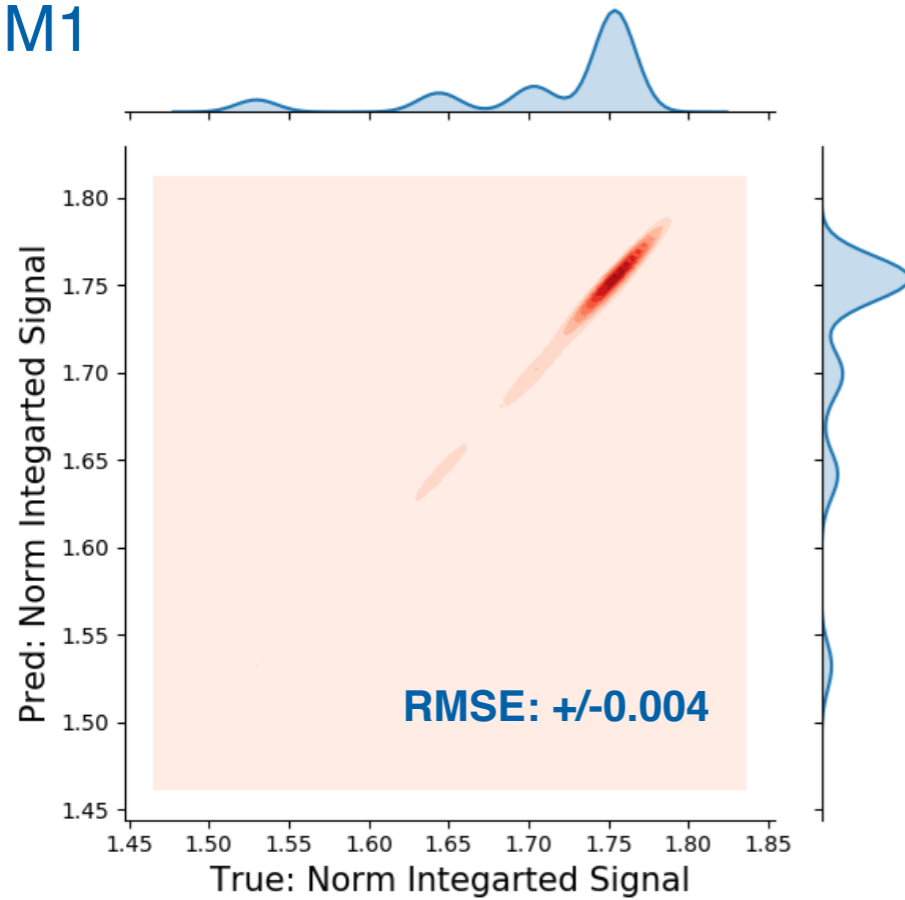
# Integrated Signal Prediction

- **Neural Network with 4 inputs:**  
**Beam Intensity, Horn Current, Beam Position X and Y**
- **3 hidden layer with 15, 8 and 7 nodes**
- **2 Output:**  
**Normalized Integrated signals (MM1,2)**
- **Training is done for new target data**

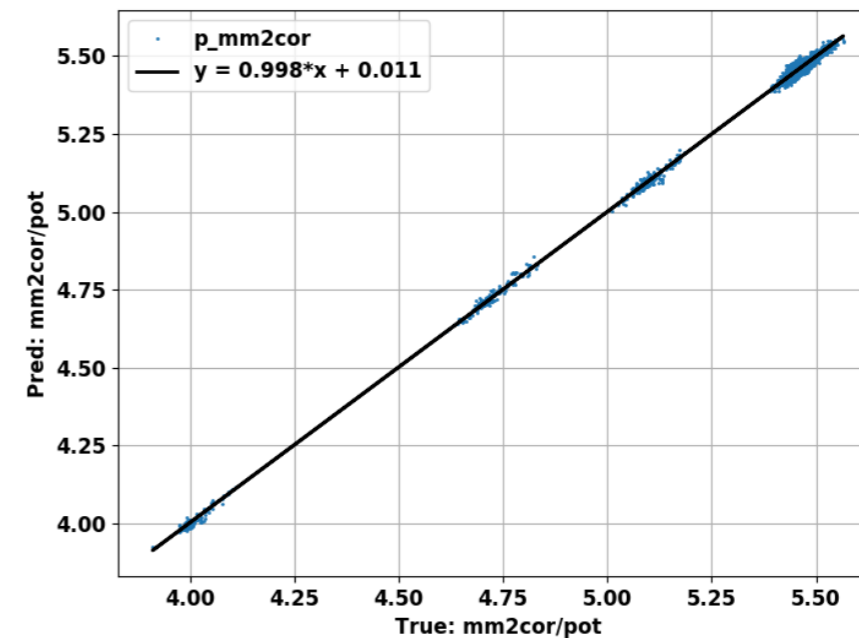
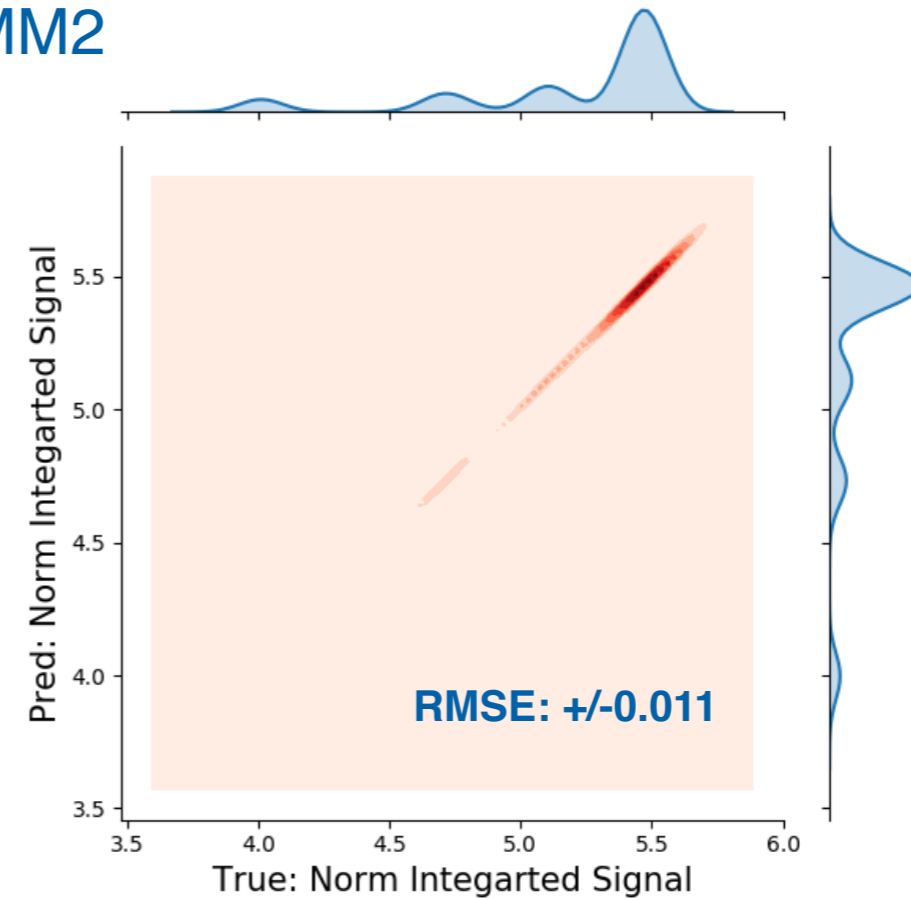


# Integrated Signal Prediction

MM1



MM2



# Incident identifying variable

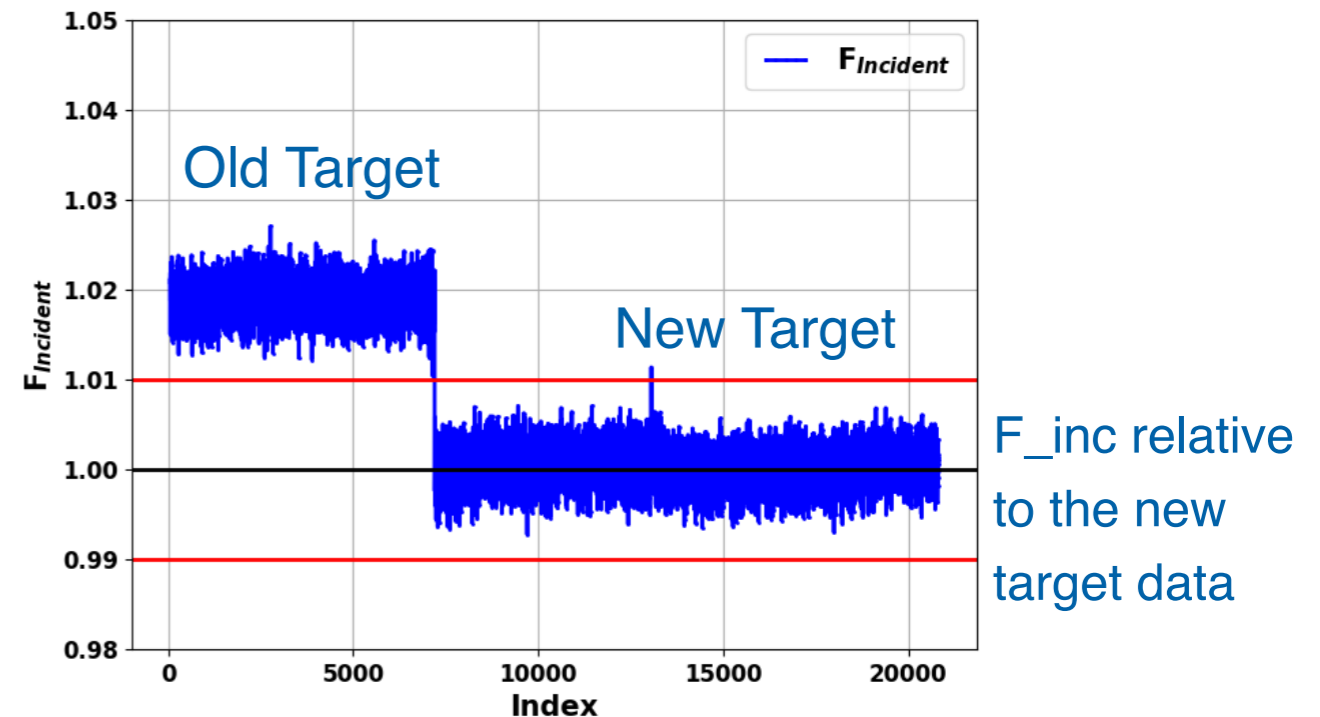
Defining a term to test the incidents:

Incident identifying variable

$$F_{Incident} = \left[ \frac{MM1COR}{MM2COR} \right]_{Pred} \cdot \left[ \frac{MM2COR}{MM1COR} \right]_{Data}$$

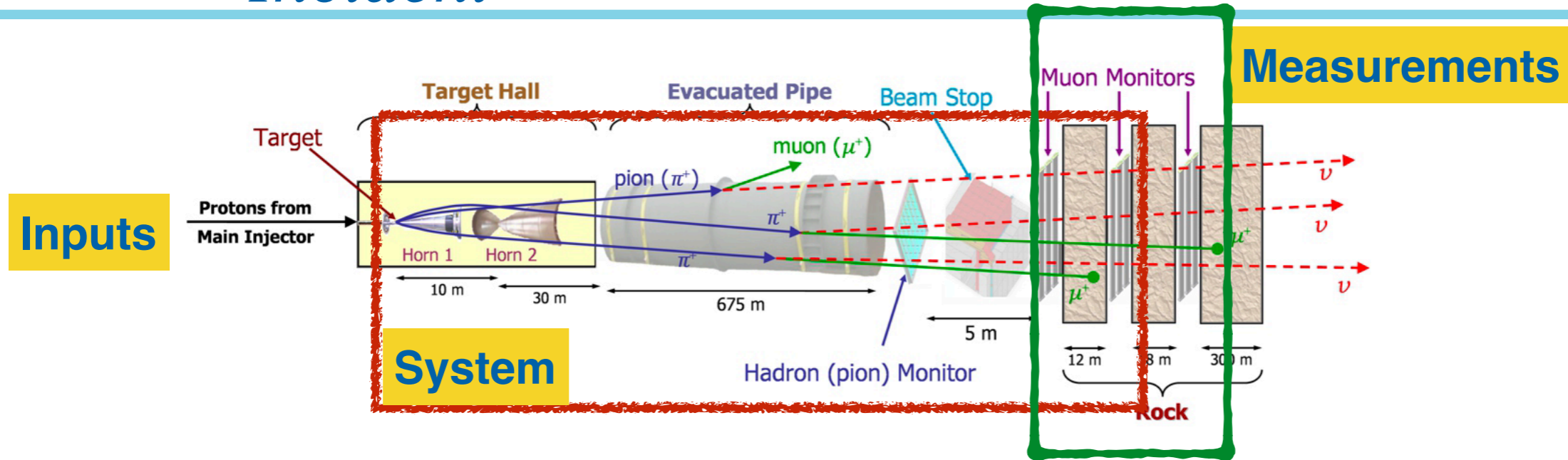
This fraction cancels out:

- Horn current dependence
- Beam related dependence
- Model dependence



This F test has a sensitivity to identify the issues in the beamline system

# How $F_{Incident}$ works?



$$\left[ \frac{MM1COR}{MM2COR} \right]_{Pred}$$

$$\left[ \frac{MM2COR}{MM1COR} \right]_{Data}$$

- MM#COR predictions depend on the inputs
- Model weights have been tuned to the 2020 MM data that is affected by the system which we had during the data recording time
- Does not depend on the run time system status

- MM#COR measurements depend on the inputs
- Depends on run time system status

If  $F_{Incident}$  is independent from the inputs, then it depends only on the system status

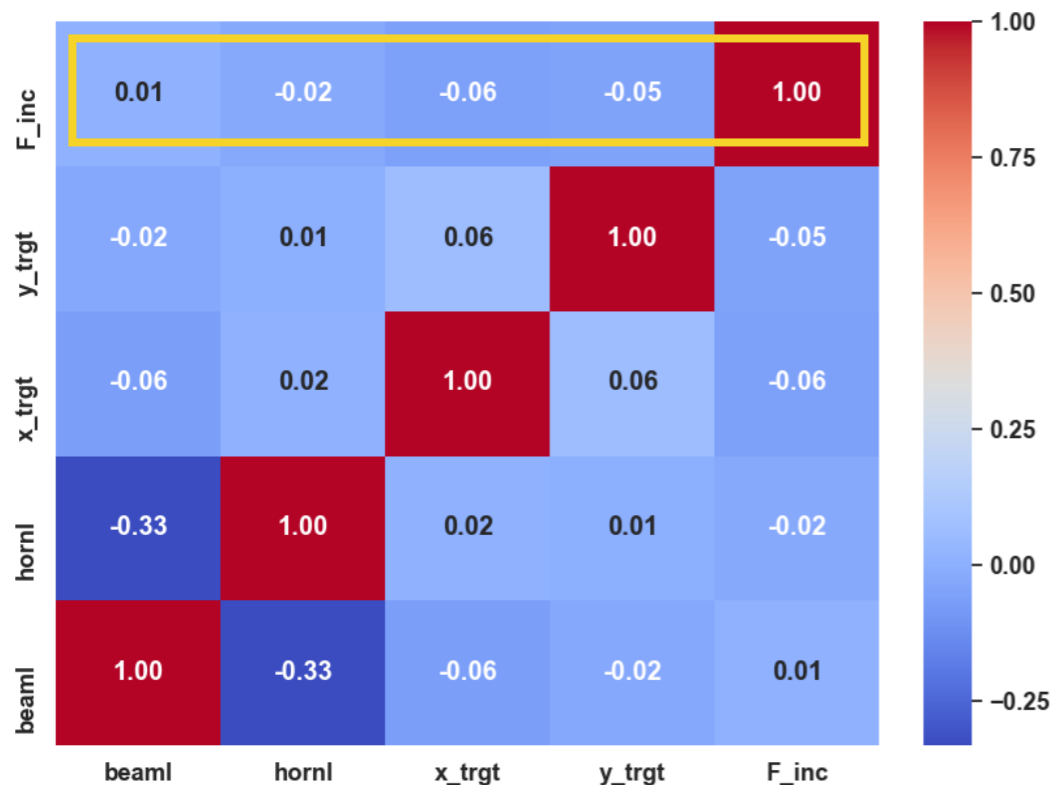
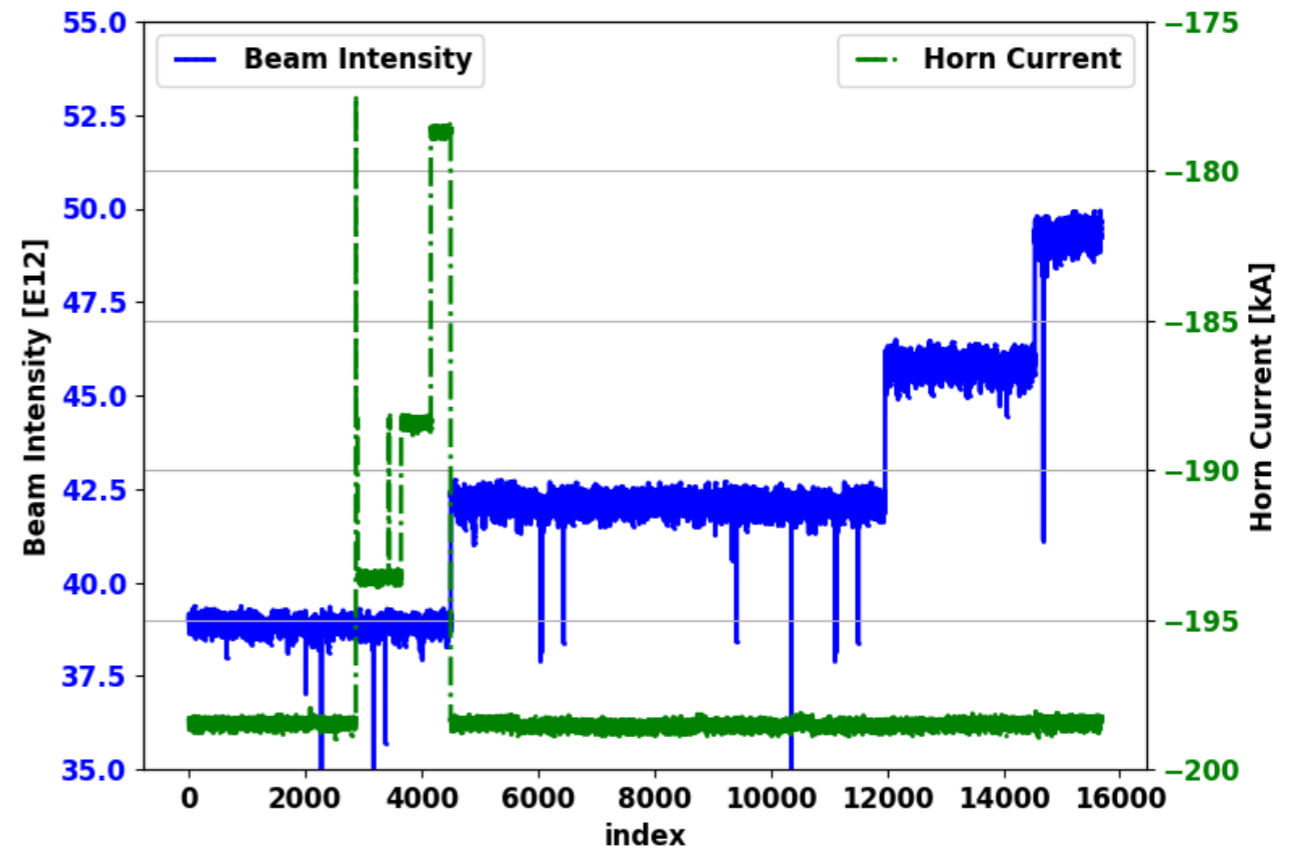
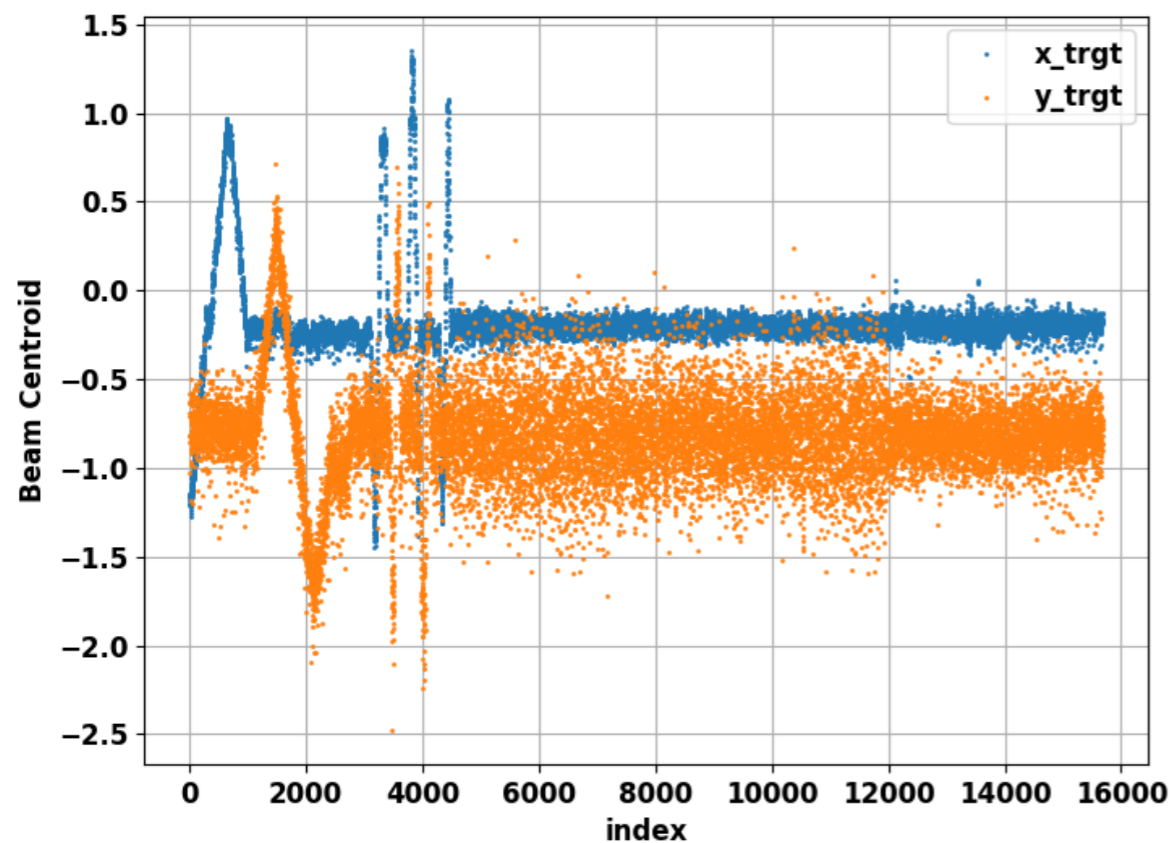
# Sensitivity of $F_{Incident}$

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**This variable may sensitive to following issues:**

- **Incidents related to the target system**
- **Things could go wrong with the horn system**
- **Incidents with the decay pipe such as gas leak**
- **Issues related to the absorber blocks**
- **Muon minitor detector failures**

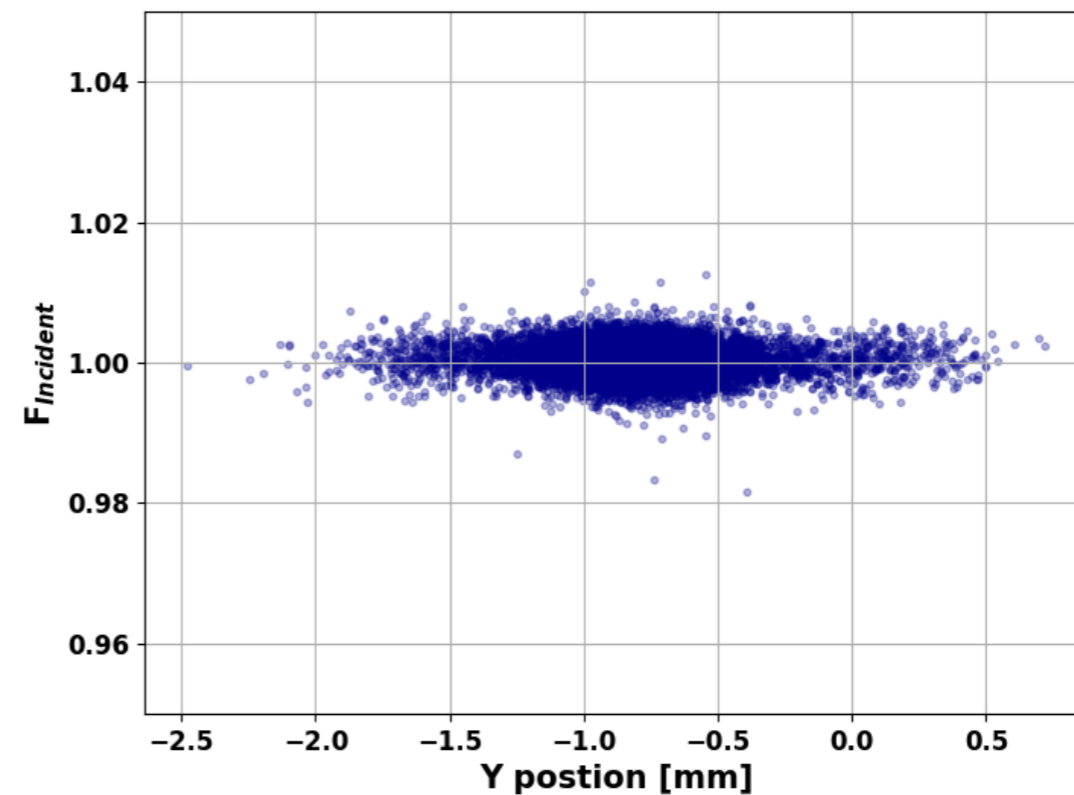
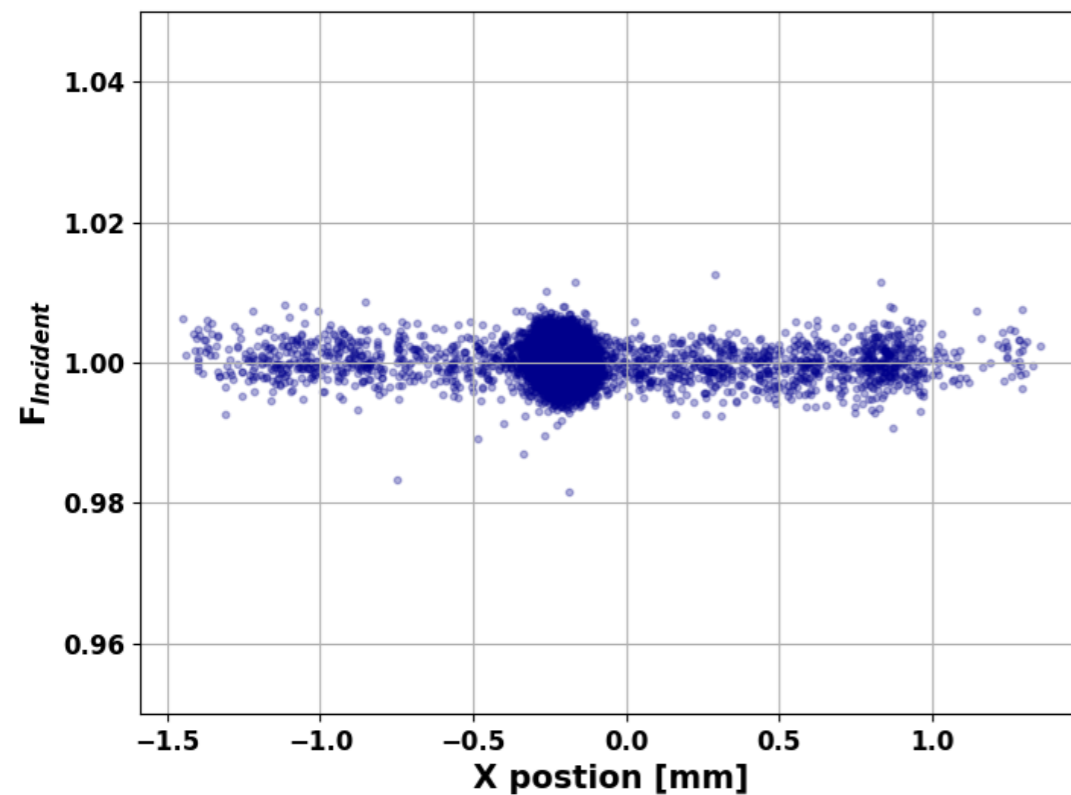
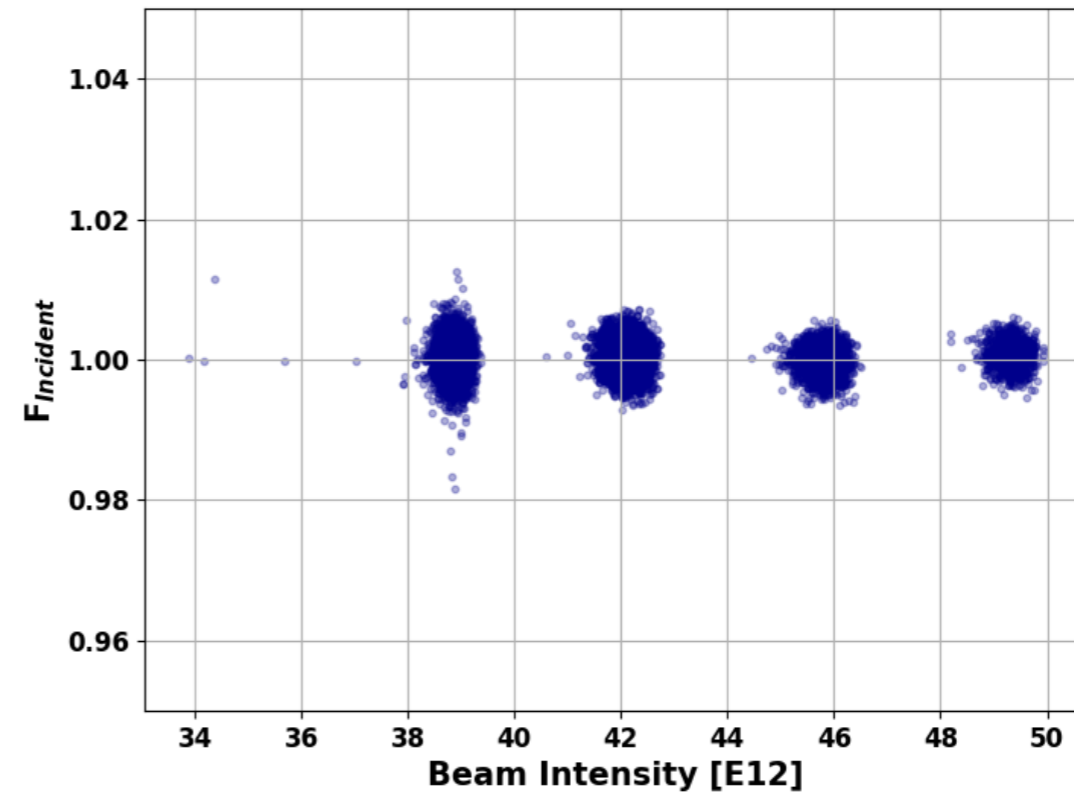
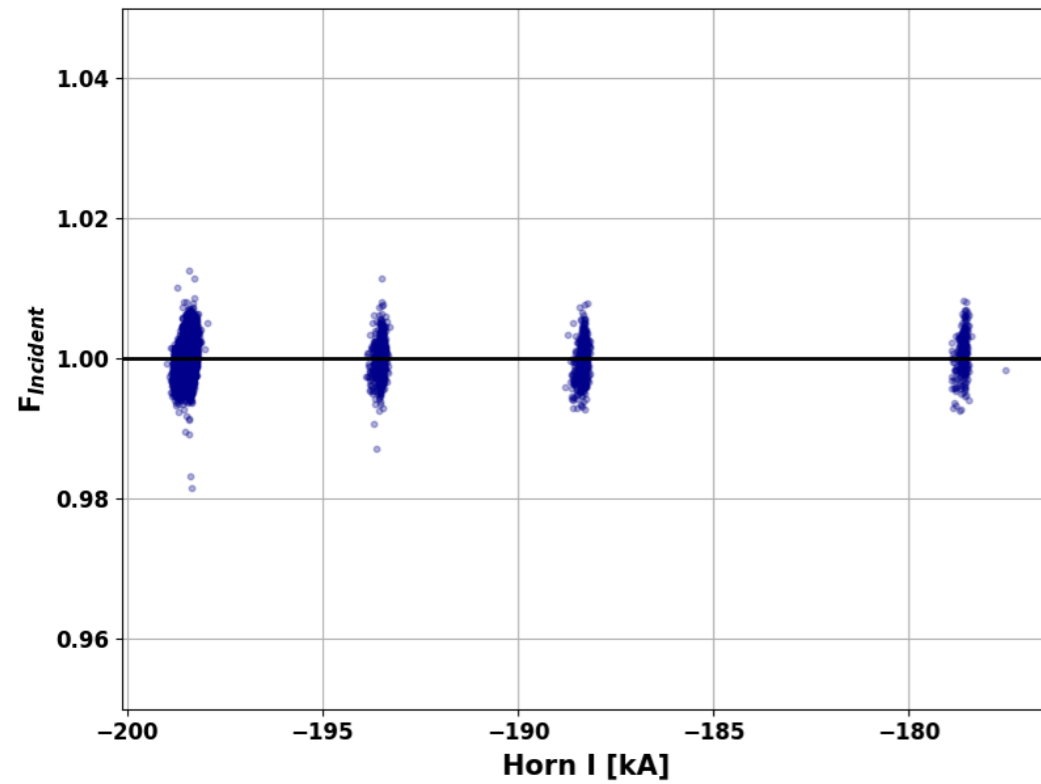
# Testing the Correlations



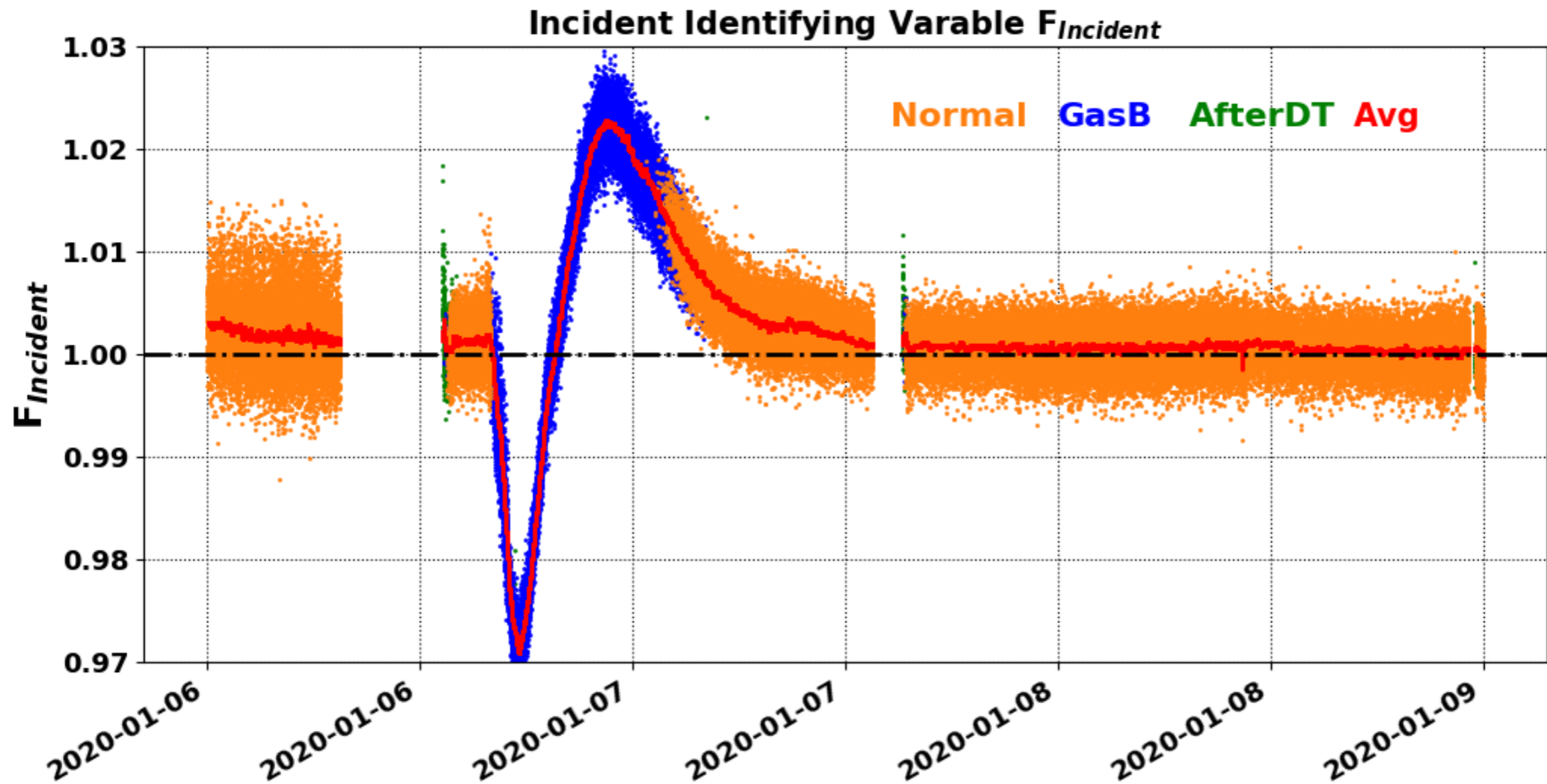
## Correlation matrix

- » Incident identifying variable is independent from the beam parameters and horn current
- » Katsuya showed me some nonlinear correlations of muon monitor signal to the horn current at around 200kA.
- » That helped me to improve the algorithm predictions by taking account the nonlinear effects

# Correlation plots

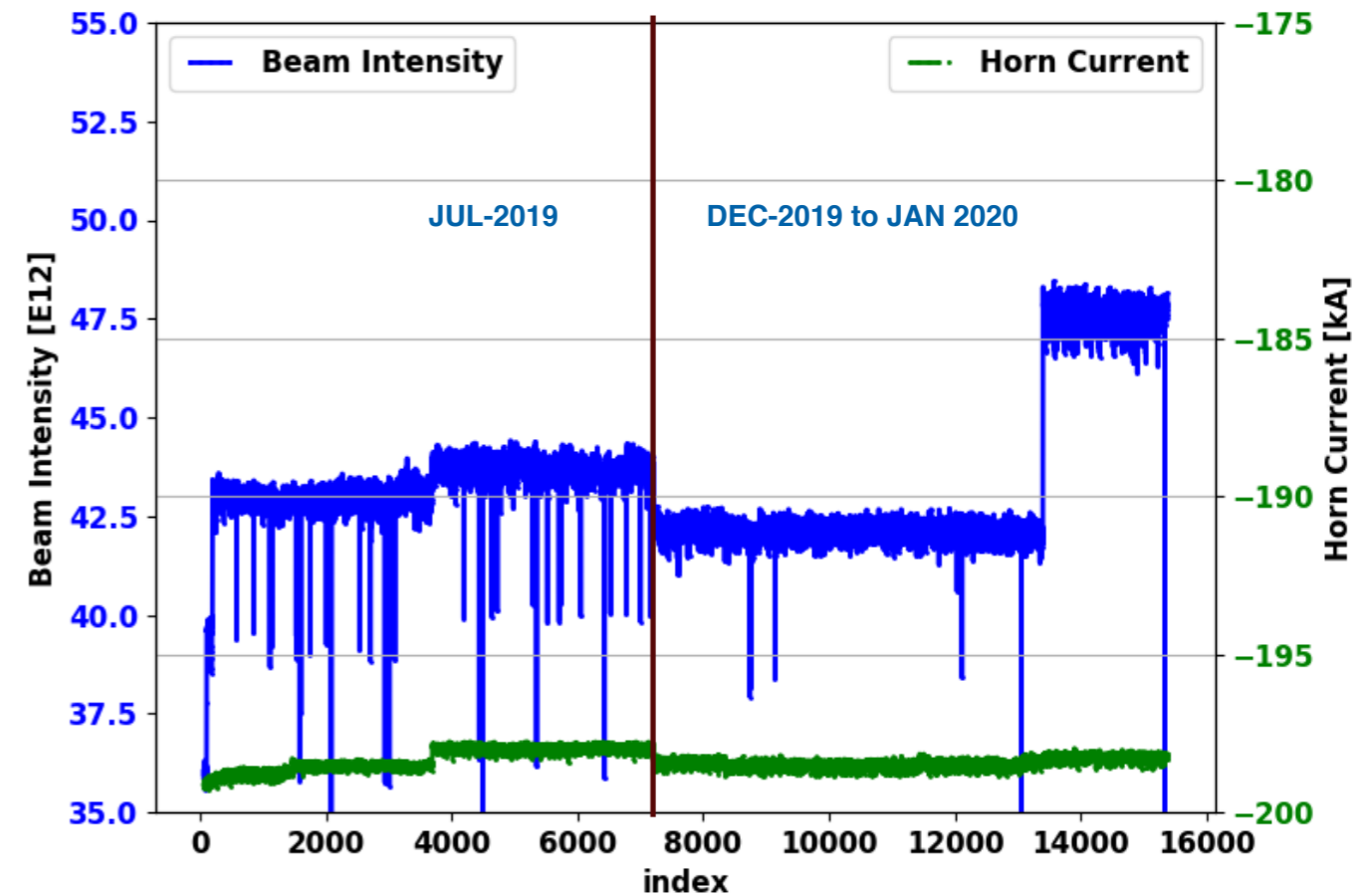
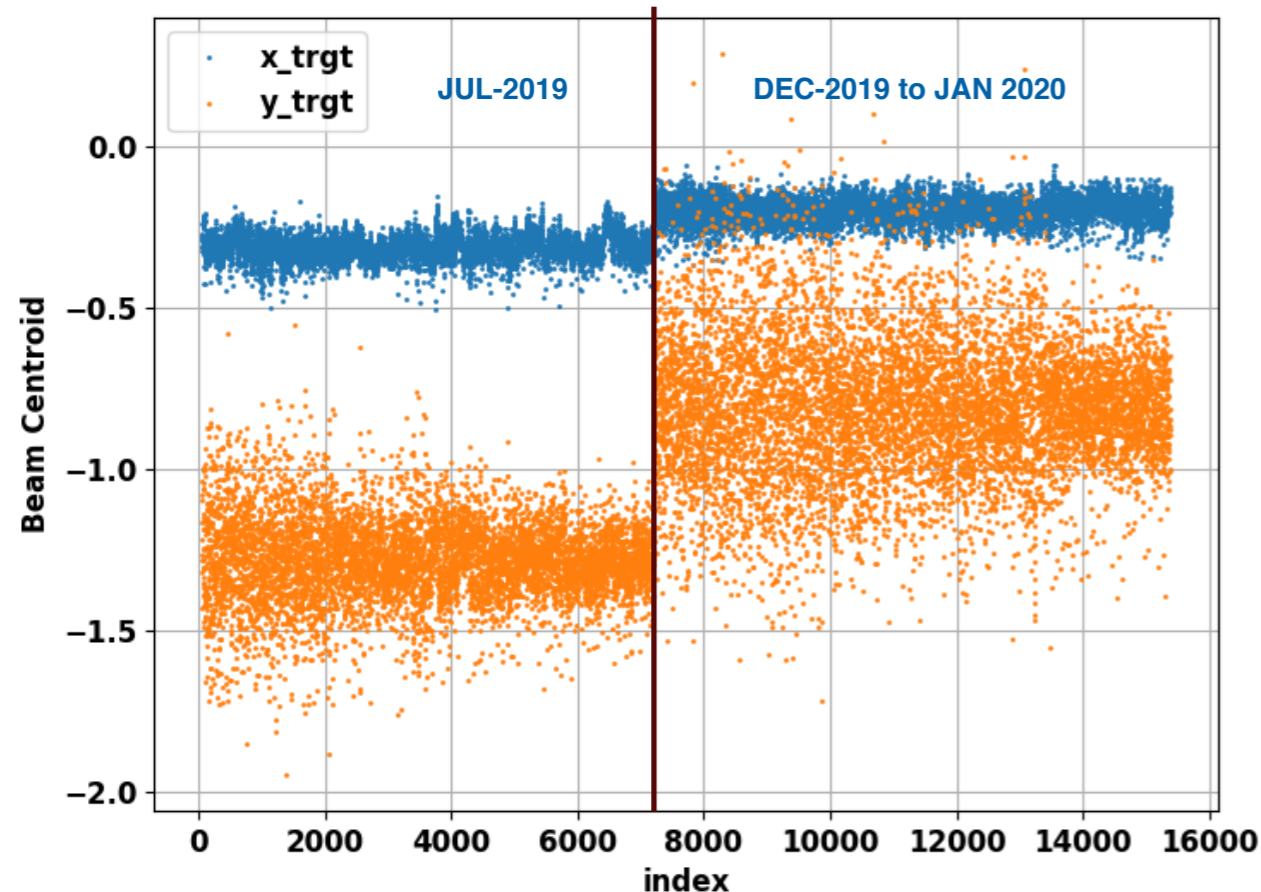


# Testing $F_{Incident}$



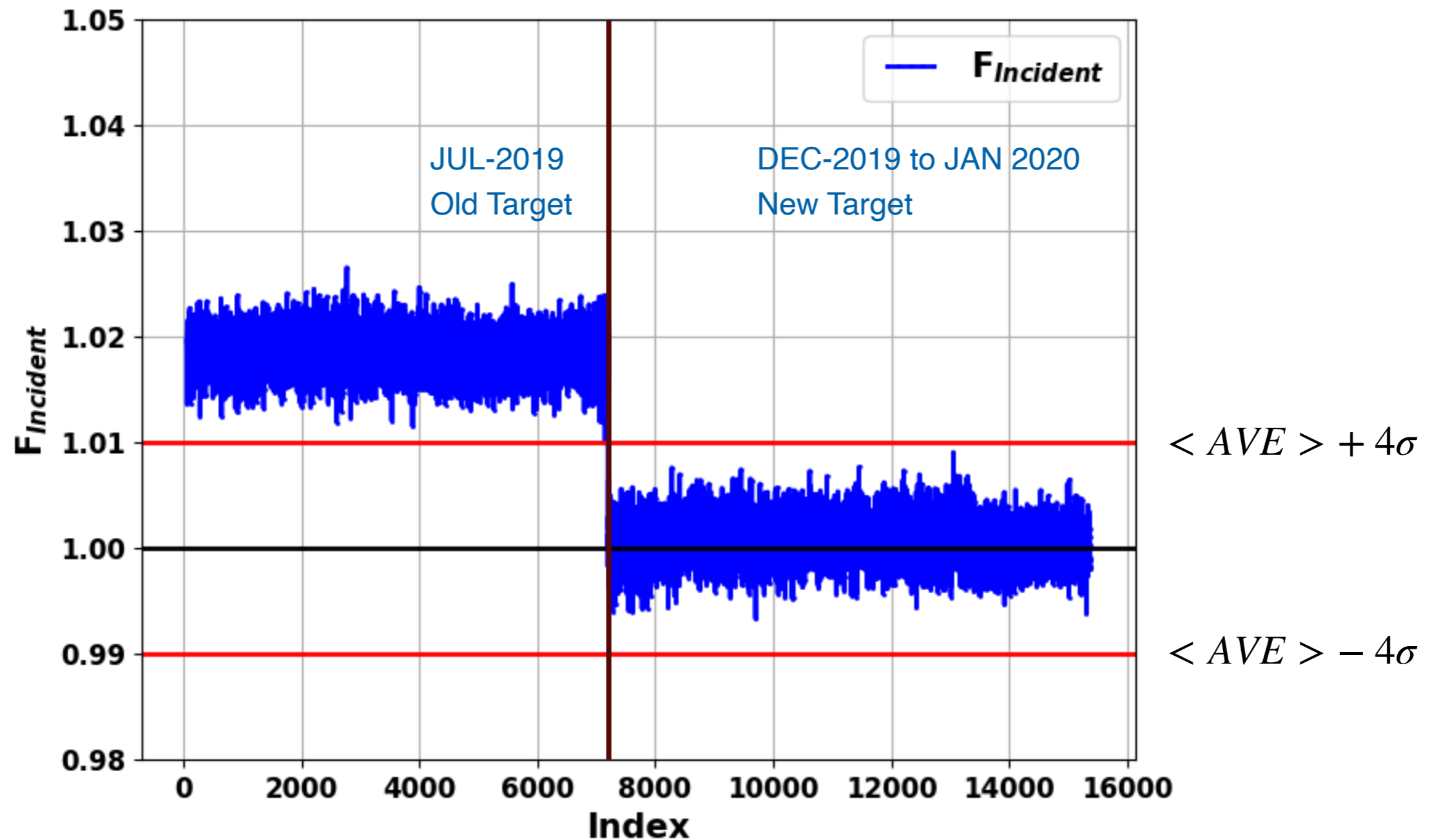
# Testing $F_{Incident}$ with Old and New Targets

We have selected a random data sample from the old and new target operations



That data looks fuzzy and has different beam and horn current operations

# Testing $F_{Incident}$ with Old and New Targets



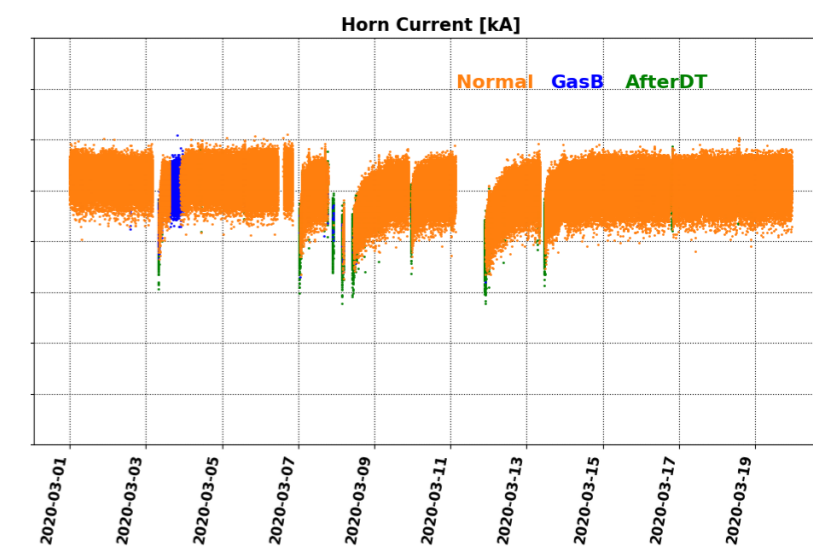
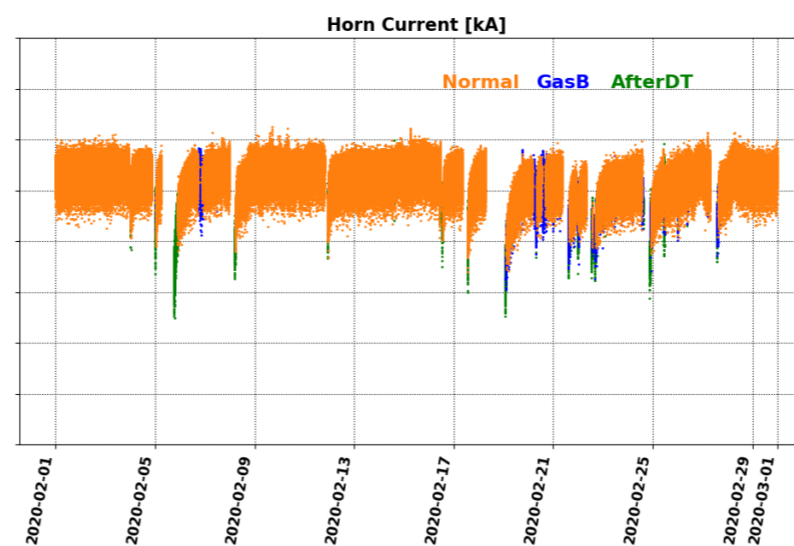
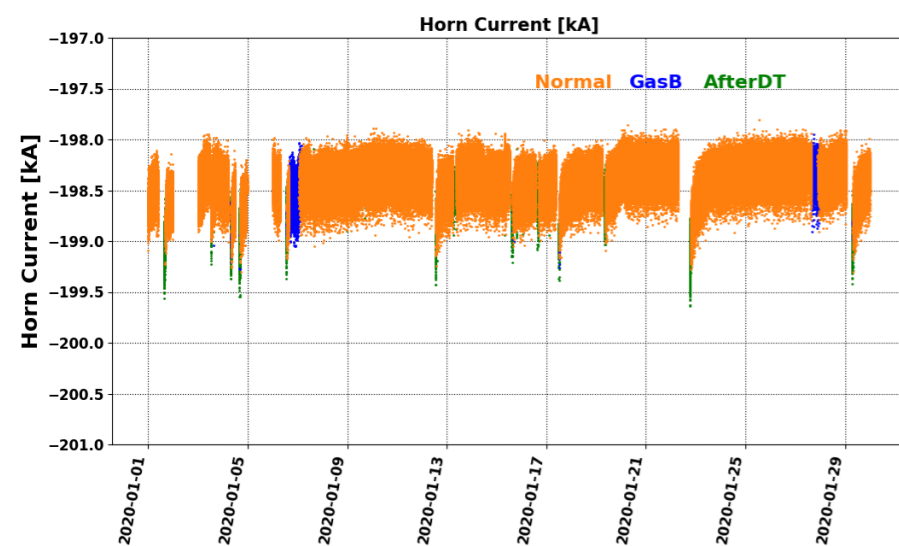
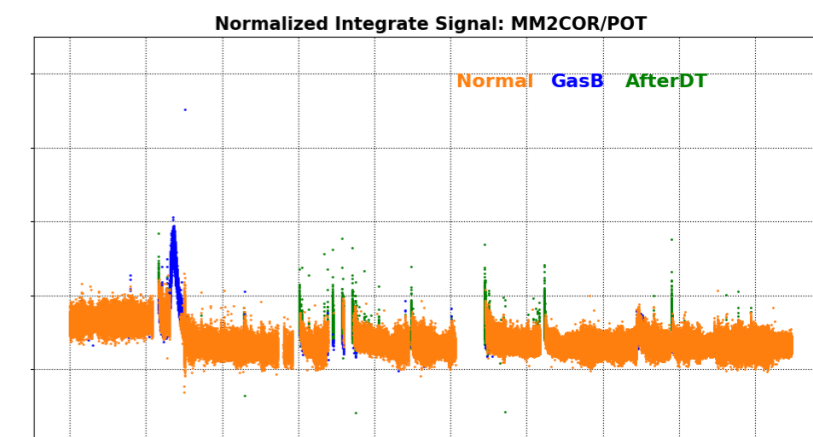
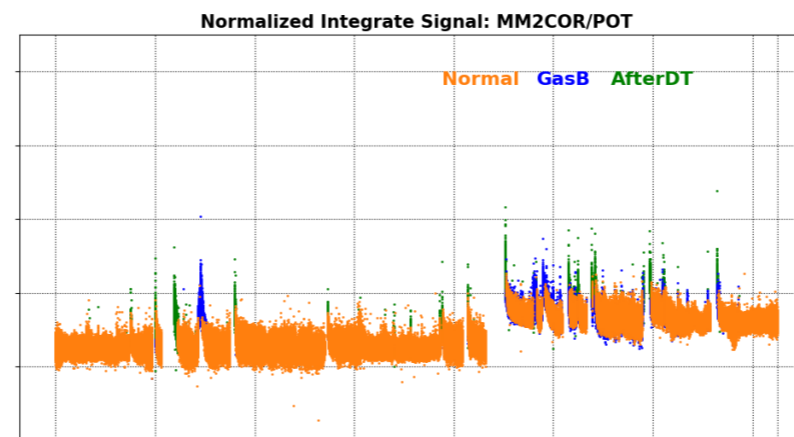
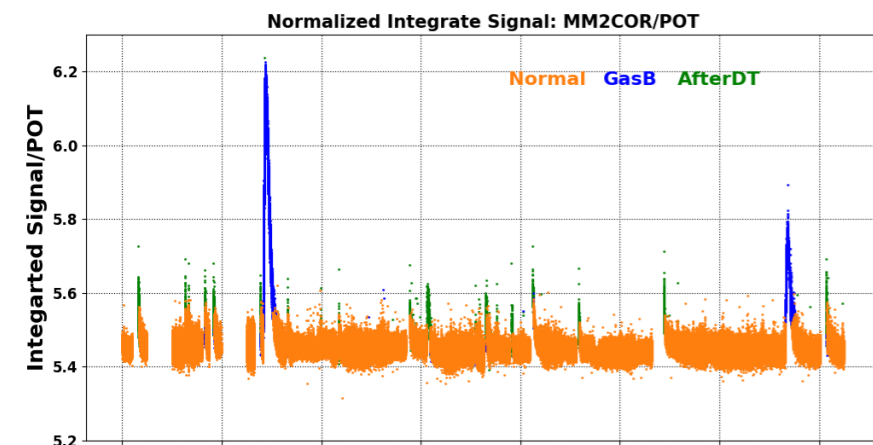
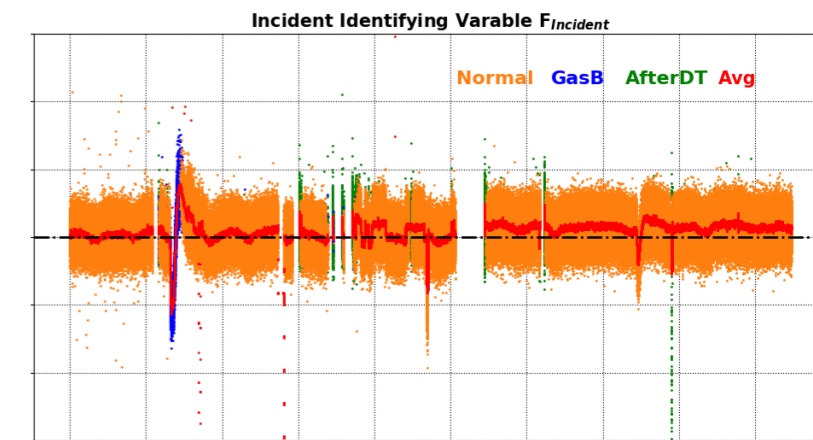
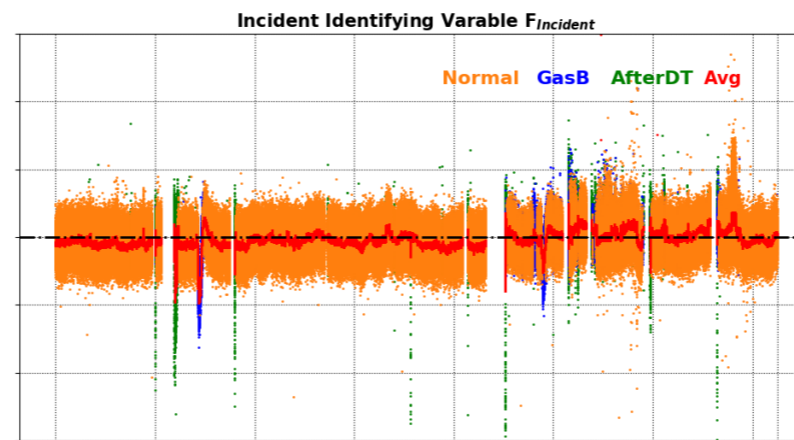
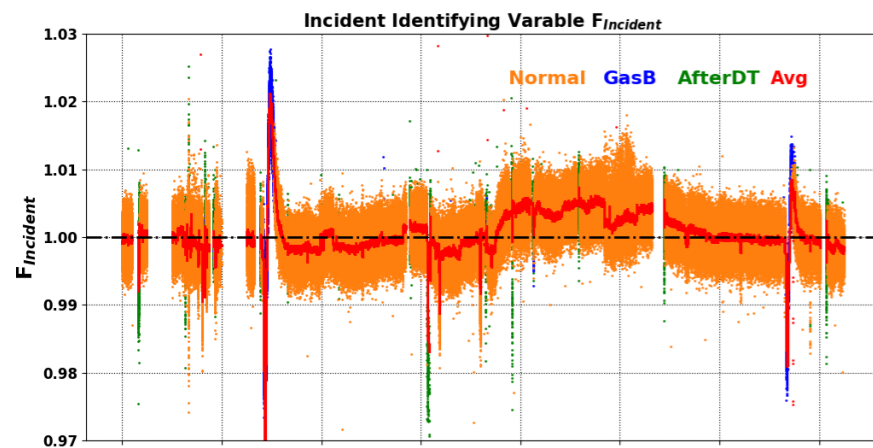
According to the comparisons of two target operations, the incident identifying variable shows the target change clearly

# $F_{Incident}$ Jan - Mar 2020

## January

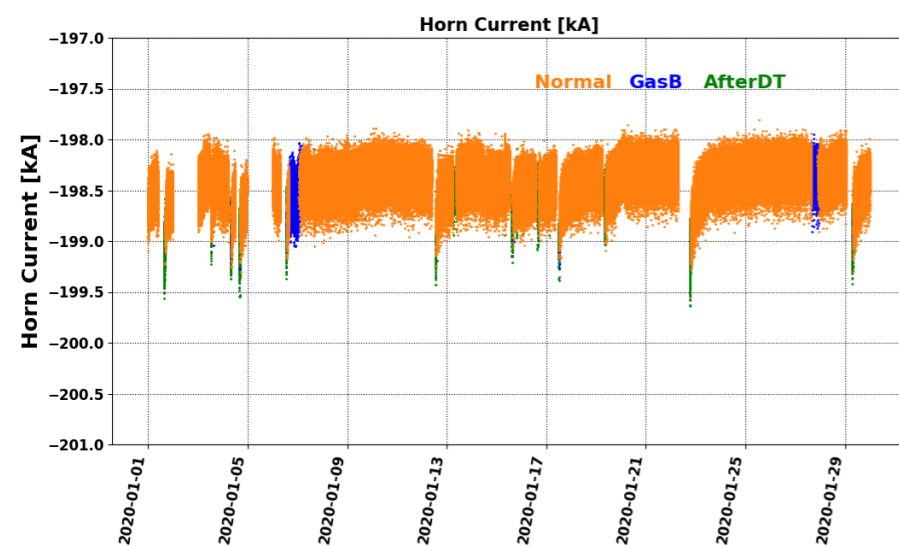
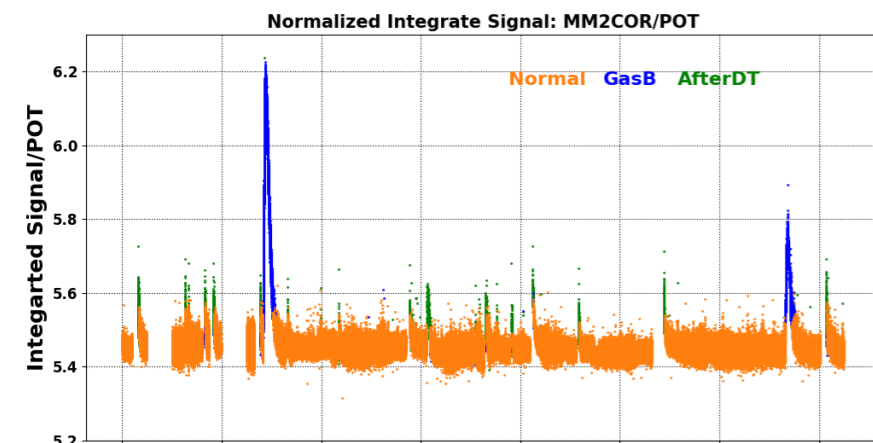
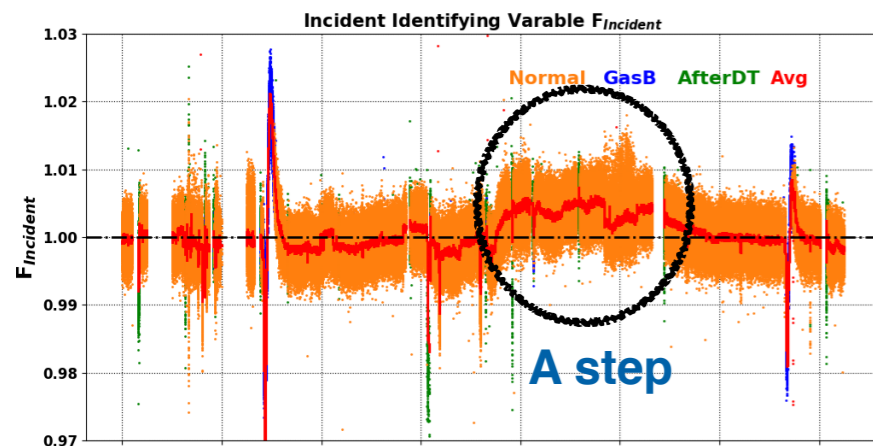
## February

## March

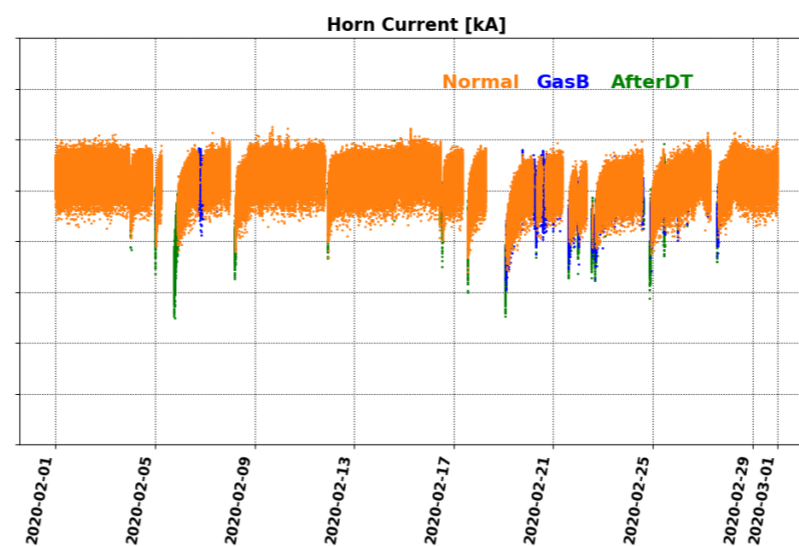
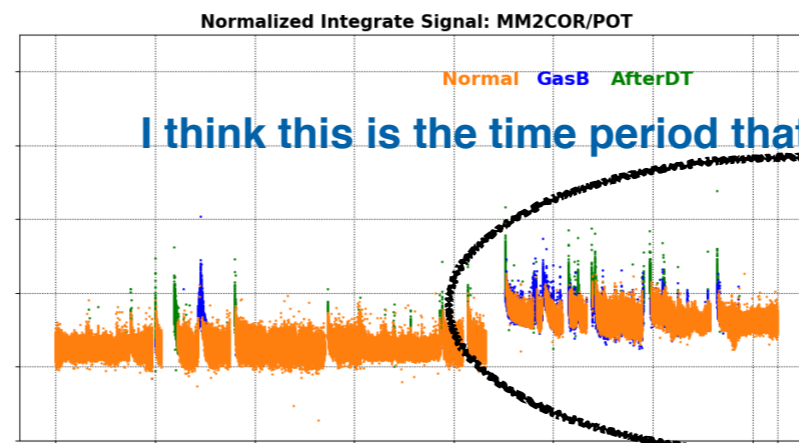
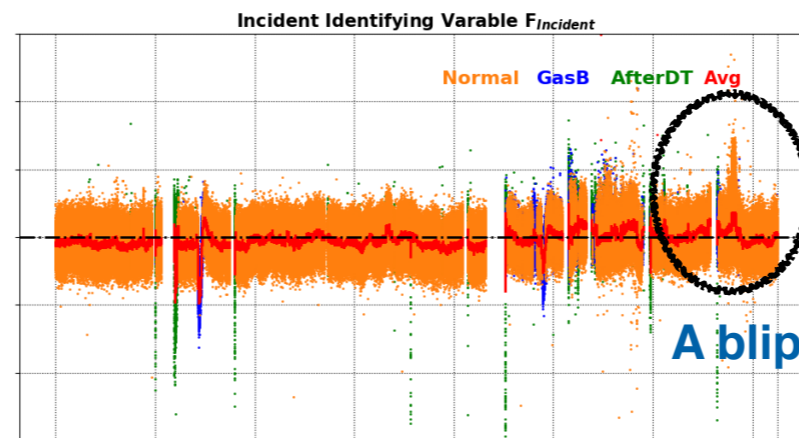


# $F_{Incident}$ Jan - Mar 2020

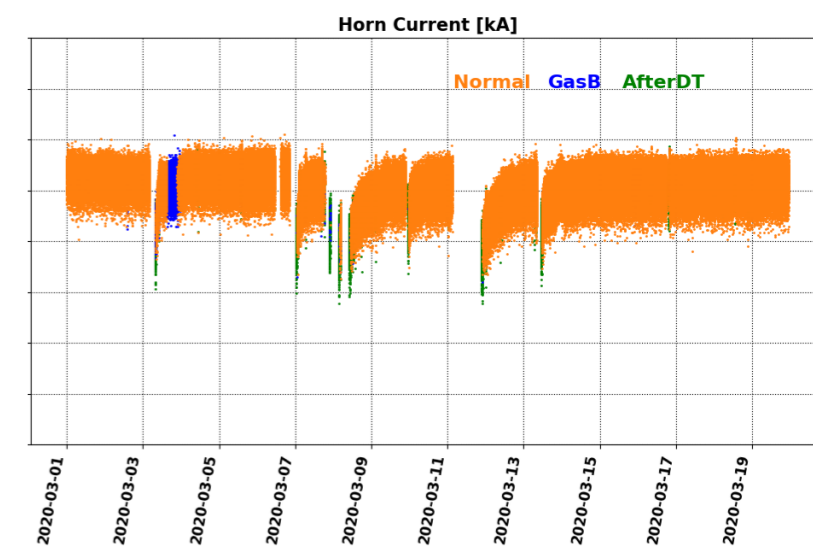
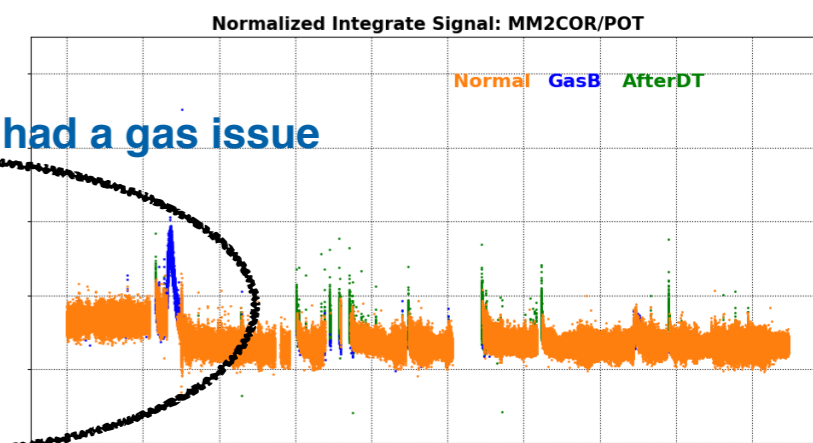
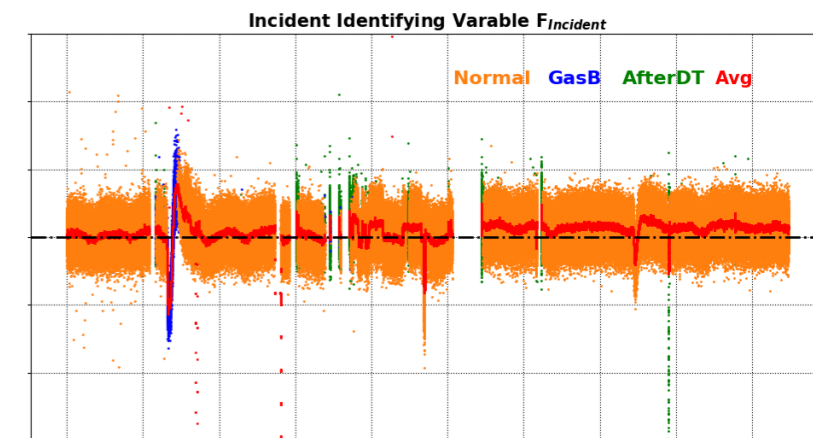
## January



## February

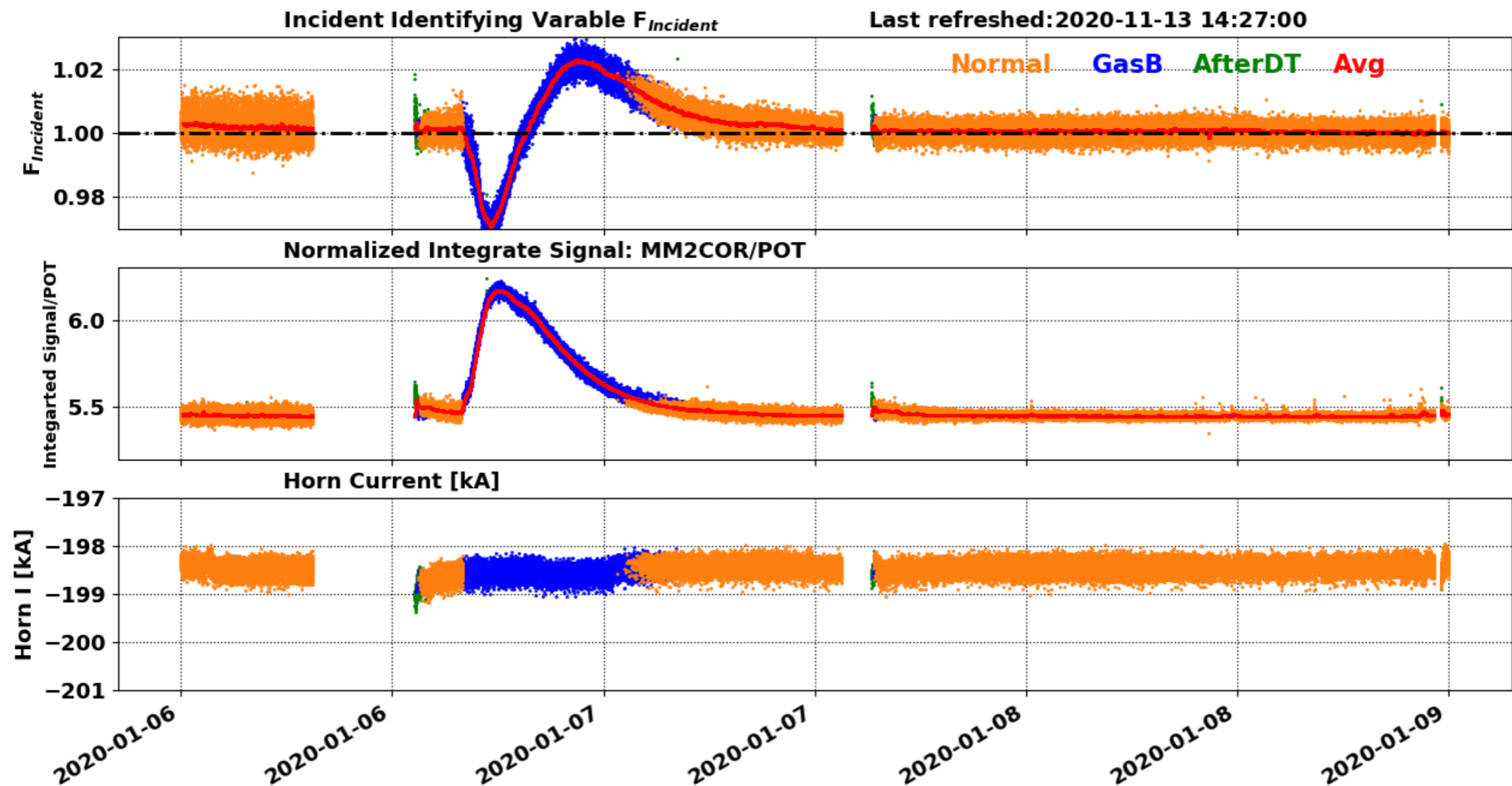


## March



# Proposing new plots for NOvA

- We would like to study the muon monitor responses for the past 24 hrs runs to understand the beam quality
- Plots are updated every 8 hrs



# Remarks and Conclusions

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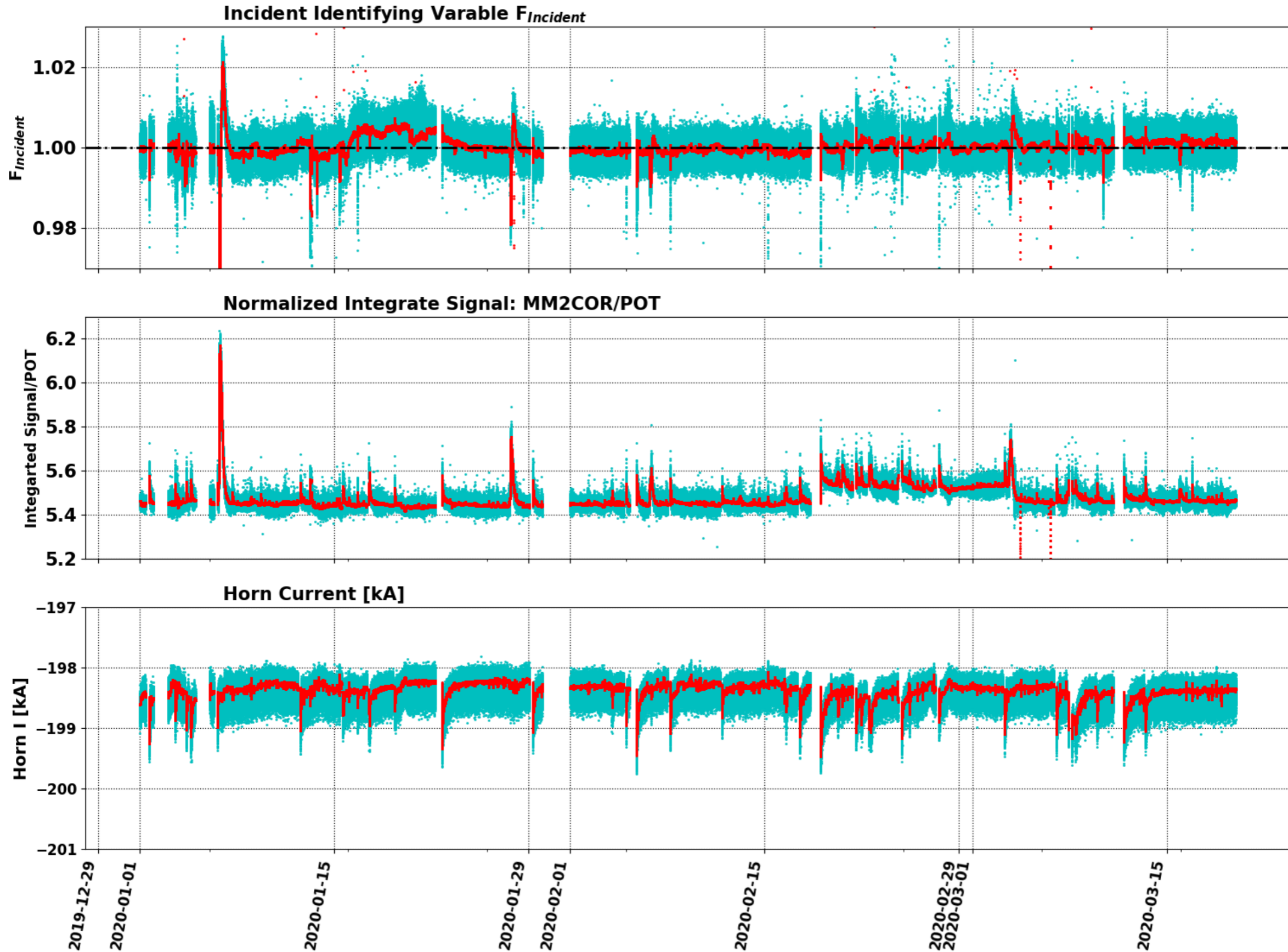
- ✦ ML algorithm works well on predicting the status of the MM observations
- ✦ We will optimize the model to improve the accuracy of the predictions
- ✦ We have introduced an incident identifying variable with combining measurement and prediction to address the system related issues
- ✦ This incident identifying variable is independent from the beam parameters and horn current
- ✦ Need to understand other possible dependencies for  $F_{\text{incident}}$
- ✦ Waiting to update and test the algorithm with FY21 beam and horn current scans
- ✦ We are planning to setup this status predating algorithm for beam monitoring

Thank you!

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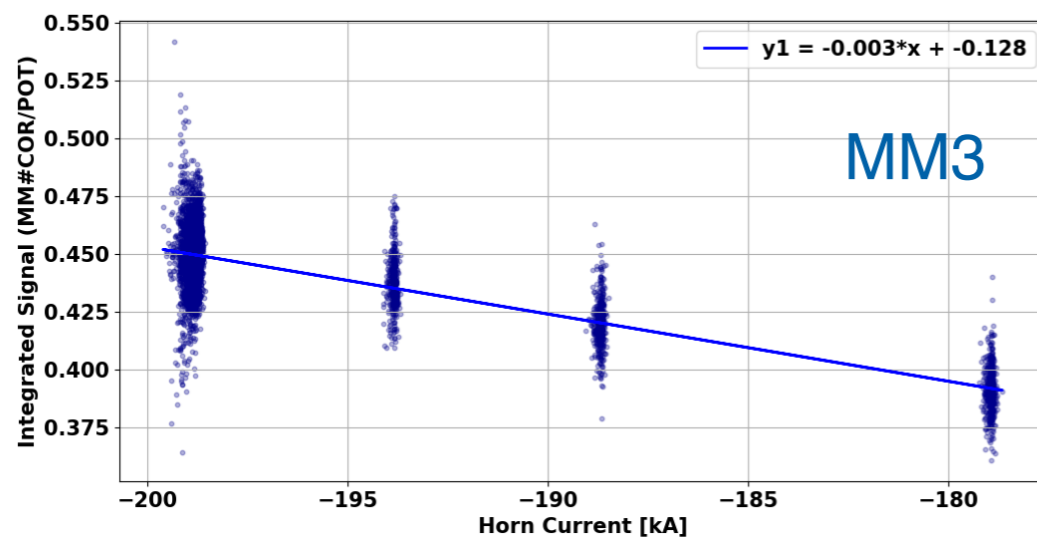
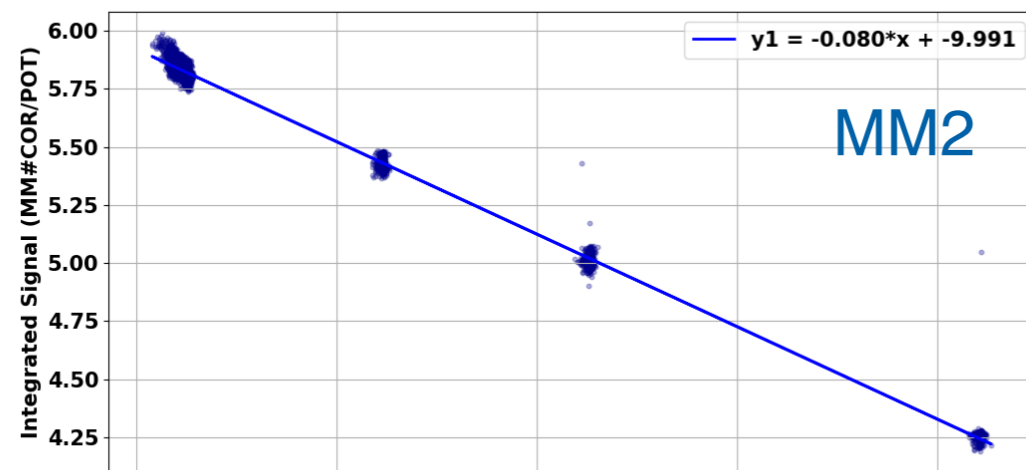
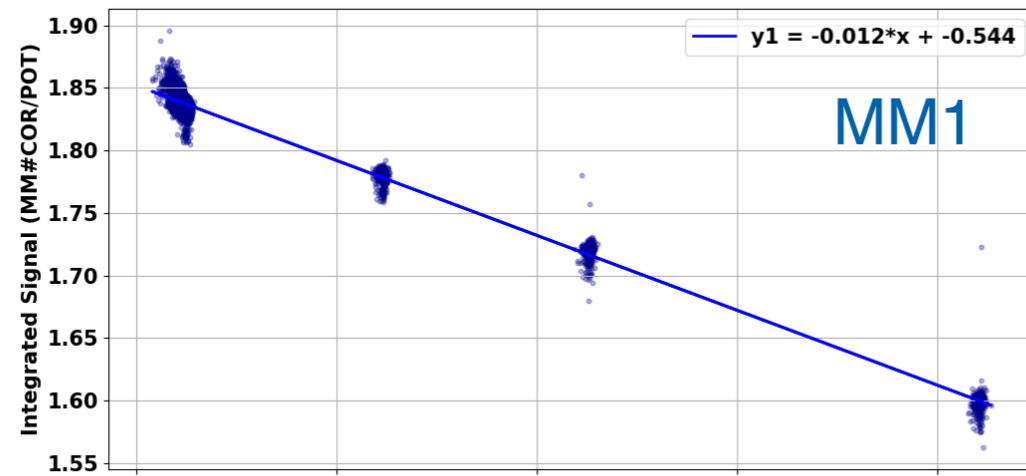
# Backup Slides

# $F_{Incident}$ Jan - Mar 2020



# Integrated Muon Signal vs Horn Current

Scan data: 2019-07-03



Scan data: 2019-12-12

